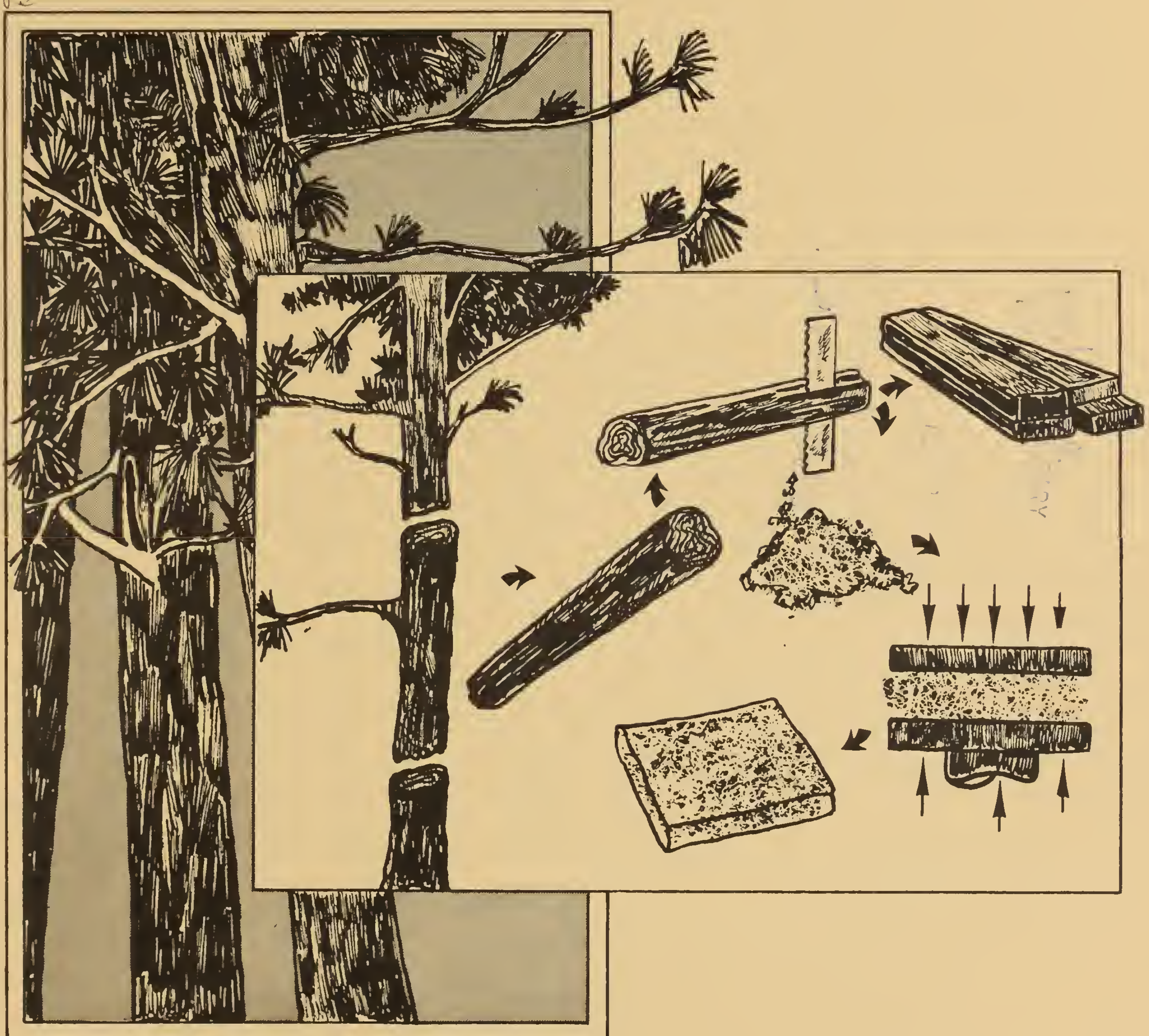
# Economic Potentials for Particleboard Production in the Black Hills

Donald C. Markstrom and Harold E. Worth



Resource Bulletin RM-5
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

## Abstract

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard per year (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The plant would be capable of producing underlayment, mobile home decking, and industrial board, using mill residues as the main wood raw material, with the possibilities for supplementing these with a smaller fraction of forest residues. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area, because of the substantial freight cost advantage.

USDA Forest Service
Resource Bulletin RM-5

May 1981

# Economic Potentials for Particleboard Production in the Black Hills

Donald C. Markstrom, Wood Technologist
and
Harold E. Worth, Principal Market Analyst
Rocky Mountain Forest and Range Experiment Station[1]

[1] *Headquarters is in Fort Collins, in cooperation with Colorado State University.*

## CONTENTS

# Economic Potentials for Particleboard Production in the Black Hills

Donald C. Markstrom and Harold E. Worth

## Management Implications

This paper is a discussion of the second of two studies of the potential for producing particleboard from ponderosa pine. This research is needed by prospective investors, wood plant managers with surpluses of raw material (residues), and land managers with an excess of small roundwood to help them assess the potential of producing particleboard from these materials. The conclusion of the first study (Markstrom et al. 1976) was that particleboard could be manufactured from ponderosa pine mill and logging residues to meet standard requirements for interior and exterior uses. This second study is an evaluation of marketing and manufacturing particleboard and produced the following conclusions:

Ponderosa pine is a preferred species for the manufacture of all types of particleboard, including industrial board, where surface characteristics are important for printing or overlaying.

Marketing factors and the wood raw material supply indicate that the manufacturing process should be designed to produce Type 1 particleboard for underlayment; mobile home decking; and industrial uses, such as furniture core, cabinets, door core, and general purpose stock. Type 1 particleboards are those made with urea-formaldehyde or equivalent bonding systems; Type 2 particleboards are those made with phenol-formaldehyde or equivalent bonding systems as defined in ANSI standard A208.1 for particleboard. Type 1 particleboard would be made from sawdust, planer shavings, coarse mill residues, and logging residues. Type 2 board may be produced if the process is modified. Bark would be used for fuel but not for particleboard furnish.

The north central United States appears to be a prime market area for Black Hills particleboard. Projected demand for the region is 993 million square feet (MM ft²), 3/4-inch basis, by 1980 and 1.8 MMM ft² by 1990. Production within the region is projected to be 320 MM ft² by 1980—at least 673 MM ft² less than needed.

The Black Hills would have both lower rail and truck freight rates than the western and southern producing regions for shipments to Denver, Colo.; Des Moines, Iowa; Minneapolis, Minn.; and Omaha, Nebr., and lower truck freight rates to Chicago, Ill. Shipments destined for Chicago; Des Moines; Kansas City, Mo.; Milwaukee, Wisc.; Minneapolis; and Omaha could be shipped from the Black Hills at a freight advantage averaging $30 per M ft² over shipments from other western plants.

Analysis of three different sized plants for the Black Hills indicated that large economies of scale would result primarily from more efficient use of labor, overhead, and capital investment. The smallest plant projected—33 MM ft² per year—could not be expected to generate adequate earnings and would likely run into severe financial difficulties during weak market periods. The largest plant—100 MM ft² per year—could be expected to produce attractive financial returns, at typical levels of market price, and should have strong survival capacity in the soft markets that are to be expected based on past cyclical record of demand for particleboard.

This study was performed concurrently with a study on the economic potential of producing plywood in the Black Hills.

## Introduction

The idea of producing particleboard in the Black Hills area of South Dakota and Wyoming is not new with potential plant investors, present wood plant managers, and land managers. Several factors have stimulated interest in particleboard manufacture. One factor stimulating this interest is the existence of a large surplus of raw materials (residues) from primary and secondary wood processing operations. Approximately 35% of the mill residue was utilized during 1971 with more than 60,000 tons of pulp chips shipped to Lake State pulpmills (South Dakota Department of Game, Fish and Parks 1974). Tightened burning restrictions make disposal of the excess residues a serious problem. Further, the cost of shipping pulp chips to the Lake States is rising rapidly and may threaten that market. A second factor stimulating interest in particleboard production is that this industry is more compatible with existing Black Hills industries than any other new forest-based industry. The particleboard industry would not compete with the sawmills for the sawtimber stumpage but would aid the sawmills

in using their residues. A third factor is that particleboard could provide outlets for some of the small roundwood excess that needs to be harvested to improve management of the area's forests. The fourth factor is that use of these presently unutilized resources would enhance general economic conditions in the area.

The overall question is whether a Black Hills particleboard producer could derive sufficient advantage from his geographic location, available raw material, existing and/or foreseeable production techniques, production costs, or uniqueness of his products to compete under present or prospective industry conditions.

In a previous technical evaluation conducted in a laboratory, Markstrom et al. (1976) manufactured and tested different types of particleboard using Black Hills ponderosa pine sawmill and logging residues. Results indicated that Type 1 boards produced from Black Hills ponderosa pine would meet standard requirements for floor underlayment, D-2 mobile home decking, and coreboard and Type 2 boards for bracing, siding, combination siding-sheathing, and combination subfloor underlayment. Six different types of board with varying particle geometry and distribution and with different resin contents and board densities were tested.

The Uniform, Basic, and National Building Codes are the model building codes used in marketing particleboard in the area. Products other than those specifically mentioned in these codes can be used by petitioning and obtaining approval from the organization governing the particular model code. The requestor must show suitability of the product by providing data and results from an independent testing agency (Applefield 1972). In addition to the building codes, which generally refer to the National Particleboard Association standards, the Federal Housing Authority, the General Services Administration, and the Department of Defense have specifications for particleboard use.

The objective of this study was to evaluate marketability of the particleboard, plant location within the Black Hills, type of plant and process characteristics, and plant investment and operating requirements and costs, including energy.

## Marketing Black Hills Particleboard[2]

### Competitive Factors

The chief product in competition with particleboard in most applications is plywood. Therefore, a careful analysis of the competitive relationship between the two is important. However, such an analysis is quite difficult because in many cases particleboard is not a direct substitute for plywood. Even when it is a substitute, the wide variety of thicknesses and types of both makes a comparison difficult. A comparison of wholesale price indices during the past 10-year period indicates that wholesale prices for all softwood plywood and plywood sheathing have risen, while prices for particleboard have been relatively stable (fig. 1). In contrast to wholesale prices, particleboard consumption has risen much faster than plywood consumption (fig. 2). A major factor in the rapid growth of particleboard consumption appears to be the lower price of particleboard relative to plywood. Growth in

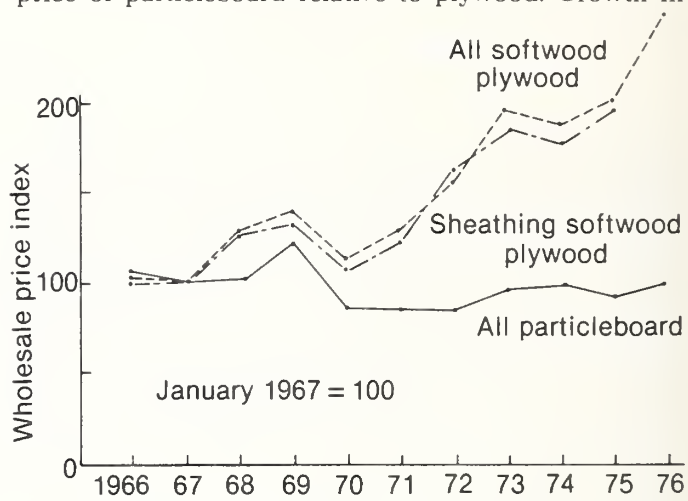



**Figure 1.—Wholesale price index for particleboard and softwood plywood 1966-1976. (After U.S. Department of Agriculture Forest Service (1977)).**

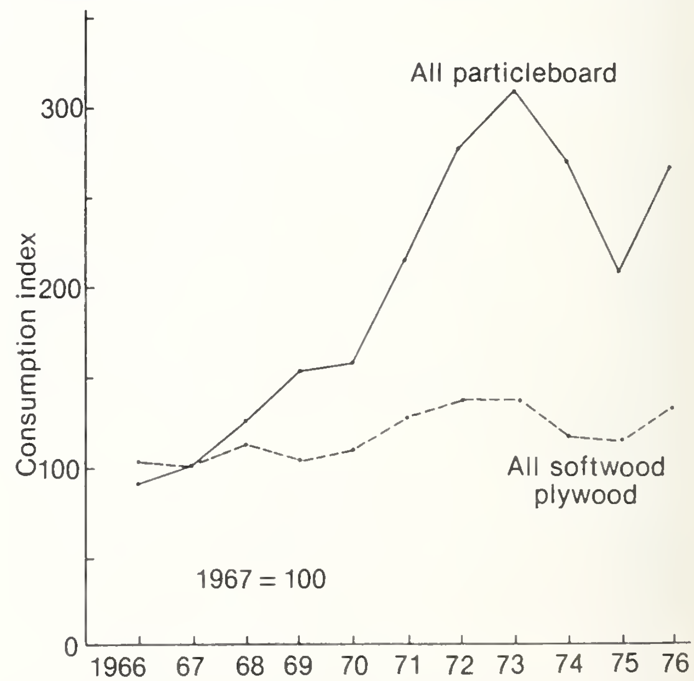



**Figure 2.—Consumption index for particleboard and softwood plywood 1966-1976. (After U.S. Department of Agriculture, Forest Service (1977)).**

[2]*The marketing portion of this paper is partially based on information from the following report: Wangaard, F. F., F. C. Shirley, R. S. Whaley, H. E. Troxell, and D. E. Eagan. 1972. Potential markets for particleboard produced in the Rocky Mountains—Phase II. Unpublished report, Colorado State University, Department of Forest and Wood Sciences, Technical Report Phase II. Rocky Mountain Forest and Range Experiment Station Research Agreement 16-229-CT, CSU Project 1473, 24 p.*

production capacity has continued to outrun demand even when demand has risen rapidly. New sources of raw material have been plentiful. It seems likely that the plywood industry, which depends on a more limited and fixed wood raw material base, will become less able to meet increasing levels of demand without consequent upheavals in price.

Unlike plywood, particleboard is available in sizes larger than 4- × 8-foot sheets and has uniformly smooth surface characteristics, especially important for floor underlayment, mobile home decking, shelving, unfinished furniture parts, and for material to be overlaid with wood veneers, vinyls, or printed for finished furniture or decorative wall paneling. However, particleboard has lower strength, higher weight, and greater vulnerability to breakage of corners and edges during rough handling.

Particleboard from some western species is generally more suitable for the manufacture of industrial particleboard products than particleboard from southern pine and most eastern hardwoods, which are consumed mainly by the underlayment and mobile home decking markets. Particleboard made from ponderosa pine generally represents the highest quality industrial and underlayment board on the market. Much of it can be used for sensitive industrial applications where surface characteristics are especially important.

Probably the most important single economic factor for a particleboard plant in the Black Hills is lower freight rates to major market areas compared to other producing areas. Delivered price often determines where a customer buys particleboard, especially commodity type boards. The delivered market price tends to be established by producers from the dominant producing region, this being the West Coast at present. The West Coast delivered price consists of the cost of manufacture, including an acceptable profit, plus the cost of transporation to the market area. The profitability for a plant in the Black Hills thus will be greatly affected by freight differentials between the Black Hills and the West Coast locations.

Railroad and common carrier truck freight rates from the Black Hills and other production locations to selected market locations are shown in tables A-1 and A-2. The production locations were selected on the basis of having production facilities that would be potentially competitive with a Black Hills plant in supplying the selected market locations. The market locations were selected because they use large volumes of particleboard but do not have nearby production facilities. Railroad rates were analyzed for shipments from nine production locations to fifteen market locations. Production locations were Whitewood, S. Dak.; Newcastle, Wyo.; Portland, Oreg.; Missoula, Mont.; Gaylord, Mich.; Crossett, Ark.; Birmingham, Ala.; Charlotte, N. C.; and Diboll, Tex.. Market locations were Boston, Mass.; Chicago; Denver; Des Moines; Detroit, Mich.; Kansas City; Milwaukee; Minneapolis; New York, N. Y.; Omaha; Philadelphia, Pa.; St. Louis, Mo.; Washington, D. C.; and Wichita, Kans. The two Black Hills locations have a rail freight advantage over the other producing locations to Denver, Des Moines, Minneapolis, and Omaha. Rail rates, although not as low as for products from the South or Midwest, are favorable to Chicago, Kansas City, and Milwaukee when compared to products from Portland and Missoula. The rail freight differential between the Black Hills and the West Coast to market areas are as follows:

| Market location | Freight differential (West Coast rate minus Black Hills rate) |
|---|---|
| | *dollars per M ft², 3/4-in basis* |
| Chicago | 33.07 |
| Denver | 17.25 |
| Des Moines | 38.52 |
| Kansas City | 32.77 |
| Milwaukee | 33.64 |
| Minneapolis | 33.06 |
| Omaha | 41.40 |

Even at market locations where South and Midwest producers have a freight advantage, an unfulfilled demand for particleboard in the market area should provide a potential outlet for Black Hills particleboard.

Particleboard producers often utilize truck transportation where no rail lines exist, where rail is inconvenient for the customer, where loads are small, or where truck rates are cheaper than rail rates. Truck rates were analyzed by us for shipments from six production locations to eight locations in the western portion of the market area. The production locations were Whitewood, S. Dak.; Newcastle, Wyo.; Portland; Missoula; Crossett, Ark.; and Diboll, Tex. The market locations were Chicago; Denver; Des Moines; Kansas City; Minneapolis; Omaha; St. Louis; and Witchita. The two Black Hills locations have truck freight rate advantage to Chicago, Denver, Des Moines, Minneapolis, and Omaha. These truck rates from the Black Hills are potentially competitive with the rail rates, especially if the receiving firm is not on a rail siding. The truck rates given in table A-2 are commodity rates as quoted by Motor Common Carrier, and may be higher than either proprietary carriers or negotiated contract arrangements.

### Distribution Channels

Basically, markets for particleboard may be divided into two groups: construction and industrial. The structure of the construction market is essentially that of producer-wholesaler-retailer-end user, the latter being mostly building contractors. Smaller amounts are retailed to industrial firms and do-it-yourselfers.

Most of the particleboard for the industrial market, including mobile home decking, specialized furniture, partitions, and fixture stock, passes directly from the particleboard plant to the end user through an inte-

grated distribution system of the manufacturer. Some particleboard plants cater exclusively to certain segments of the furniture industry. Figure 3 illustrates the major distribution channels for particleboard.

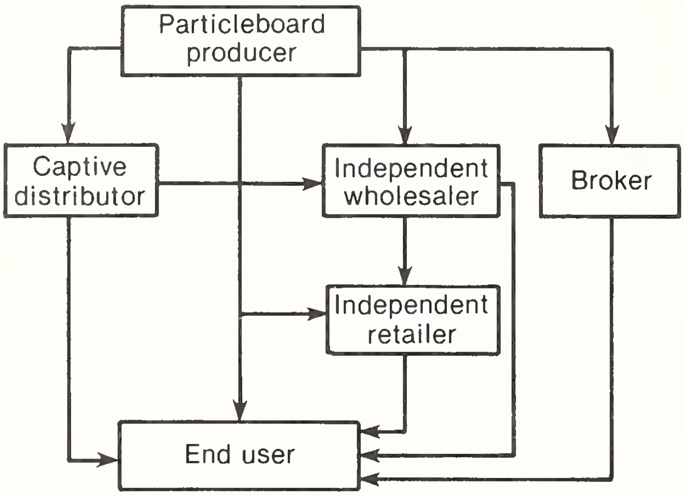



Figure 3.—Main distribution channels for particleboard.

### Current Consumption and Production Within Market Area

The North Central Region of Indiana, Ohio, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North and South Dakota, Nebraska, and Kansas, as used by the Bureau of the Census, plus Colorado and Wyoming, is the prime market area for Black Hills particleboard, based on differences between volumes of production and consumption and the transportation advantage that Black Hills producers have in this area. The existing particleboard production capacity by state for 1980 within the market area is estimated to be (Dickerhoof and McKeever 1979):

| **State** | **Production capacity** |
|---|---|
| | *MM ft², 3/4-in basis* |
| Colorado | 0 |
| Illinois | 0 |
| Indiana | 24 |
| Iowa | 0 |
| Kansas | 0 |
| Michigan | 165 |
| Minnesota | 45 |
| Missouri | 0 |
| Nebraska | 0 |
| North Dakota | 0 |
| Ohio | 0 |
| South Dakota | 0 |
| Wisconsin | 86 |
| Wyoming | 0 |
| Total | 320 |

Projections made for this study indicate that demand will increase in the north central region from 993 MM ft² in 1980 to 1800 MM ft² in 1990 (table A-3). A 1980 deficit (consumption less production capacity) for the north central region of 673 MM ft² is probably a conservative estimate of the market potential for that area, since actual production seldom reaches the rated capacity of all the plants in the area.

### Projected Consumption

Future consumption of particleboard was projected for end-use categories to determine the type of particleboard product that would find markets. Review of the literature indicated projections of consumption were available on a national basis but were not separated into different end-use categories and smaller market areas needed for this study (United States Department of Agriculture, Forest Service 1979). Consumption figures for different end-uses in the north central region were therefore projected for this study (table A-3).

Particleboard use figures for the north central region through 1990 were determined from national projections by us after making the following two assumptions: (1) There are no regional differences in the consumption and (2) the particleboard consumed in a region for a particular industry is proportional to the value of shipments of the finished products originating from that region. For example, if 20% of wood household furniture shipments originated in the north central region; it was assumed that 20% of the particleboard was consumed by the wood household furniture industry in the north central region.

National use projections in table A-4 were based by us on two growth factors: the projected growth of the particular industry using the particleboard, and the projected use of particleboard for each industry, measured in square feet per unit produced or in square feet per dollar value of shipments. Available growth and particleboard usage data for one- and two-family, multi-family, and mobile homes were used to project consumption of particleboard for these industries (table A-5). No reliable growth data could be found for the uses of nonresidential construction, repairs and remodeling, wood household furniture, wood office furniture, partitions and fixtures, recreational vehicles, modular homes, and general manufacturing. Consequently, the value of shipments for these industries was projected through 1990, assuming the value of shipments to be correlated with gross national product (fig. A-1, table A-6). Linear least square regression lines were fitted to the value of shipments and gross national data from 1958 to 1975. All gross national product and shipment values were deflated to 1958 prices in an effort to negate the effects of inflation. The pattern of the plotted data points indicated that straight lines fitted the data generally as well as curvilinear lines and would be useful to project the overall trend of shipment values.

The increased usage of particleboard by a particular industry was projected on the basis of published data or the authors' assumptions. The projected consumption in the north central region for the different enduses is summarized below:

**Residential Construction.**—Particleboard use in the residential construction category, including single-family and multi-family in both the private and public sectors, will rise from 152 MM $ft^2$ during 1980 to 242 MM $ft^2$ during 1990. Particleboard in residential construction is used for underlayment, millwork, trim, shelving, and a limited amount of paneling. Further development of structural particleboard could increase the usage of particleboard significantly for roof sheathing or structural flooring.

**Repairs and Remodeling.**—The annual consumption of particleboard for repairs and remodeling is projected to increase from 81 MM $ft^2$ during 1980 to 142 MM $ft^2$ during 1990. The increase reflects large amounts of particleboard going into urban renewal projects. Also reflected is increased use of particleboard by homeowners for remodeling.

**Nonresidential Construction.**—This category represents all construction activity minus residential construction and repairs and remodeling. Increased use of particleboard per dollar of nonresidential construction activity is not expected to rise rapidly. The amount of particleboard consumed is expected to rise from 21 MM $ft^2$ to 33 MM $ft^2$ between 1980 and 1990.

Opportunities to use particleboard in nonresidential construction are few. Most floors in nonresidential buildings are concrete; thus, underlayment is unnecessary. Development of a reusable moisture resistant structural particleboard that could compete with plywood in concrete forms could cause substantial gains for particleboard.

**Furniture and Fixtures.**—This category includes wood household furniture, wood kitchen cabinets, metal household furniture, public building furniture, partitions, and fixtures (display cases, office partitions, etc.), and miscellaneous furniture and fixtures. The annual consumption of particleboard for furniture and fixtures is expected to increase from 451 MM $ft^2$ during 1980 to 909 MM $ft^2$ during 1990. This industry shows the greatest increase in particleboard consumption of all the industries. Growth of the industry is expected to remain vigorous.

**General Manufacturing.**—This category includes particleboard used in paper mill, foundries, luggage, prefabricated metal products, sporting goods, bird feeders, morticians' goods, musical instruments, games, and toys. The growth of particleboard in categories is expected to remain relatively high as new uses are found. The consumption is expected to rise from 74 MM $ft^2$ during 1980 to 157 MM $ft^2$ during 1990.

**Mobile Homes.**—A mobile home is defined as a housing unit for year-around living designed to be towed on its own chassis and to be connected to utilities, but lacking permanent foundation. Mobile homes in this study are defined as trailer coaches over 32 feet long and wider than 8 feet. The volume of particleboard used for mobile homes will remain at approximately 104 MM $ft^2$ from 1980 to 1990. This consumption represents a low increase in unit usage and a slight decrease in the number of new units during the period. The increase will be a result of increased mobile home size and the increasing use of particleboard in counter tops and cabinets.

**Recreational Vehicles.**—Recreational vehicles include trailer coaches less than 32 feet in length, campers for mounting on pick-up trucks, and self-contained motor homes. The growth of this industry is uncertain because of future motor fuel shortages. However, use of particleboard in these vehicles is projected to increase from approximately 9 MM $ft^2$ in 1980 to 20 MM $ft^2$ in 1990.

**Modular Homes.**—Modular homes are self-contained housing units built to meet existing code and standards for site-built homes. This definition eliminates mobile homes which do not normally meet codes and standards for permanent structures.

Particleboard is used mainly for combination subfloor-underlayment. Other uses include cabinets, doors, shelving, and counter tops. These uses of particleboard are expected to climb from 45 MM $ft^2$ in 1980 to about 92 MM $ft^2$ in 1990.

## Availability and Cost of Wood Raw Materials

The availability and cost of wood raw materials for particleboard manufacture are important to the success of any particleboard manufacturing plant. Most particleboard on the market is manufactured from mill residues, largely in lumber and plywood manufacturing areas.

For the period 1977 to 1986, the estimated average annual volume of sawmill and logging residue potentially available at Black Hills production locations is 354.3 M ovendry (o.d.) tons (table 1), based on the potential yield of sawtimber from the Black Hills National Forest and an estimated allowable harvest of sawtimber from the area's state and private lands. The residues will drop to 243.5 M o.d. tons during the period 1987 to 1996, resulting from a decrease in projected sawtimber harvest on the Black Hills NF. The potential yield includes timber removed in silvicultural treatments in the Standard and Special components of the Black Hills National Forest. Logging residues include the upper stem portion beyond the minimum diameter for board foot measure, growing stock trees of less than sawtimber size destroyed during harvest, and portions of trees suitable for chips but culled as sawlogs because of crook.

About 225.1 M o.d. tons is potentially available annually at the eight sawmill centers in the area identified in table 2. This volume, a proportion of that shown in table 1, is based upon 13 mills operating at 80% of annual capacity—approximately 190 MM bf, lumber tally as during 1977. In the past, lumber production has not approached full mill capacity because of poor markets, inadequate returns, or other lack of

Table 1.—Annual volumes (M o.d. tons) of sawmill and logging residues potentially available during the time periods 1977-1986 and 1987-1996, based on the forest harvest estimates for the Black Hills NF and the allowable cut on the state, private, and other federal lands in the area

| Time period<br>Source | Sawmill residues[1] | | | Logging residues chippable[2] | Total |
|---|---|---|---|---|---|
| | Sawdust | Shavings | Chippables | | |
| 1977-1986 | | | | | |
| Black Hills NF | 98.0 | 59.5 | 100.0 | 16.3 | 273.8 |
| State, private, and other federal | 28.8 | 17.5 | 29.4 | 4.8 | 80.5 |
| Total | 126.8 | 77.0 | 129.4 | 21.1 | 354.3 |
| 1987-1996 | | | | | |
| Black Hills NF | 58.3 | 35.5 | 59.5 | 9.7 | 163.0 |
| State, private, and other federal | 28.8 | 17.5 | 29.4 | 4.8 | 80.5 |
| Total | 87.1 | 53.0 | 88.9 | 14.5 | 243.5 |

[1]*The volume of sawmill residues was calculated from forest harvest estimates of the Black Hills NF and the allowable cut on state and private lands using residue factors by Landt and Woodfin (1964). The factors were .5663 tons per M fbm rough lumber tally for sawdust, .3442 for shavings, and .5782 for chippables. Rough lumber tally was assumed to equal net Scribner log scale times 1.25 for all trees with d.b.h.* $\geq$*9.0 inches. A conversion of 6.0 fbm, rough lumber tally, per net cubic foot was assumed for trees with d.b.h. 7.0-8.9 inches.*

[2]*The net cubic foot volume of logging residues was assumed to equal 4.72% of net cubic foot volume of sawlogs harvested (Setzer 1973). The o.d. weight per cubic foot for ponderosa pine wood residue was assumed to be 24 pounds (Markstrom and Yerkes 1972).*

Table 2.—Volume of sawmill and logging residues (M o.d. tons) potentially available at eight sawmill centers in the Black Hills[1]

| Sawmill center | Estimated sawmill capacity | Sawmill residues[2] | | | Logging residues chippable[3] | Total residues |
|---|---|---|---|---|---|---|
| | | Sawdust | Shavings | Chippable | | |
| | *MM fbm (LT)*[4] | | | | | |
| Spearfish, S. Dak. | 35 | [5]7.9 | 9.6 | 16.2 | 2.4 | 36.1 |
| Hulett, Wyo. | 20 | 9.0 | 5.5 | 9.3 | 1.4 | 25.2 |
| Sturgis, S. Dak. | 12 | 5.4 | 3.3 | 5.5 | .8 | 15.0 |
| Piedmont, S. Dak. | 30 | 13.6 | 8.3 | 13.8 | 2.1 | 37.8 |
| Hill City, S. Dak. | 28 | [5]6.4 | 7.7 | 13.0 | 1.9 | 29.0 |
| Custer, S. Dak. | 20 | 9.0 | 5.5 | 9.3 | 1.4 | 25.2 |
| Newcastle, Wyo. | 20 | 9.0 | 5.5 | 9.3 | 1.4 | 25.2 |
| Whitewood, S. Dak. | 25 | 11.4 | 6.9 | 11.6 | 1.7 | 31.6 |
| Total | 190 | 71.7 | 52.3 | 88.0 | 13.1 | 225.1 |

[1]*Sawmill production was assumed to be 80% of estimated capacity.*

[2]*The volume of sawmill residues was calculated using residue factors by Landt and Woodfin (1964). The factors were .5663 tons per M fbm rough lumber tally for sawdust, .3442 for shavings, and .5782 for chippables.*

[3]*The net cubic feet of logging residues was assumed to equal 4.72% of net cubic foot volume of sawlogs harvested (Setzer 1973). The o.d. weight per cubic foot for ponderosa pine wood residue was assumed to be 24 pounds (Markstrom and Yerkes 1972).*

[4]*LT = lumber tally*

[5]*Fifty percent of sawdust produced is used to generate steam at these plants.*

economic motivation. Ten of the above mills presently have chipping facilities for coarse sawmill residues and/or logging residues and have been marketing chips. The other three mills are also of a size and location that should give them potential for chipping.

The sources of residues in descending order are chippable sawmill residues, 39%; sawdust, 32%; shavings, 23%; and chippable logging residues, 6%. The highest concentration of residues is in the northeastern portion of the Black Hills, with Spearfish, Whitewood, Sturgis, and Piedmont, S. Dak., having a potential of 120.5 M o.d. tons or 54% of the total.

In computing the cost of materials, the manufacturer typically does not include stumpage and harvesting costs. If the residues have another use, such as pulpchips or hogged fuel, the manufacturer will include the appropriate opportunity cost in the analysis; otherwise, the only costs are further processing and hauling residues from the sawmill or plywood plant to the particleboard plant. Presently, 9 of the 13 mills are

selling pulpchips to Lake States pulp mills. Further, two of the larger mills have installed wood residue fired boilers to heat the dry kilns and other mill buildings. Some mills sell minor amounts of slab and edgings for firewood and sawdust and shavings for livestock bedding.

The cost data in table 3 are based on the assumption that the value of pulpchips, f.o.b. railcar, to the sawmill operators averaged $21.00 per unit or $17.50 per o.d. ton. The value of sawdust and planer shavings loaded on chip vans at the sawmill was assumed to be $4.00 per o.d. ton. Estimating the cost of transporting chips, sawdust, and shavings from the sawmills to the particleboard plant assumed that a 10-unit chip van can be operated for $1.50 per loaded mile. At Whitewood, S. Dak., delivered cost of sawdust and shavings would range from $4.63 to $12.88 and chips from $15.50 to $26.38 per o.d. ton. At Newcastle, Wyo., sawdust and shavings cost ranges from $4.00 to $14.75 and chips from $17.50 to $28.25. The cost of these raw materials in terms of units of end product would, in addition, depend upon the type of maufacturing process, product, and the size of the facility. This aspect will be discussed later in the manufacturing cost section of the paper.

## Plant Location

Two representative prospective plant locations are used in this analysis: Whitewood, S. Dak., and Newcastle, Wyo. Whitewood is on the northeastern edge and Newcastle on the west-central edge of the Black Hills area. The criteria for selection included existence and stability of the local timber industry, presence of transportation networks suitable for use by the forest products industries, and availability of community facilities.

Three forest-related industries are operating in or around Whitewood. These firms produce lumber, pulpwood, and treated posts and poles. Five sawmills within 21 miles of Whitewood have a total annual capacity of about 100 MM fbm. The town is within 1 mile of Interstate 90 and has rail service. Whitewood is near Spearfish, Sturgis, and Rapid City, S. Dak. These communities each have well established commercial, education, and other public service facilities as well as superior outdoor recreation opportunities for hunting, fishing, and hiking.

Newcastle has one major sawmill operating with the town. The community has a rail line, as well as U.S. Highways 14 and 85. It would have similar commercial,

Table 3.—Estimated cost of residues (dollars per o.d. ton) at the sawmill and delivered to particleboard plant locations at either Whitewood, S. Dak., or Newcastle, Wyo.

| Place of delivery | Origin of residues | Mileage[1] | Hauling cost[2] | Chip costs: Sawmill[3] | Chip costs: Plant | Sawdust and shavings cost: Sawmill | Sawdust and shavings cost: Plant |
|---|---|---|---|---|---|---|---|
| To Whitewood, S. Dak. | | | | | | | |
| From | Spearfish, S. Dak. | 15 | 1.88 | 16.87 | 18.75 | 4.00 | 5.88 |
| | Hulett, Wyo. | 60 | 7.50 | 8.00 | 15.50 | 4.00 | 11.50 |
| | Sturgis, S. Dak. | 7 | .88 | 17.50 | 18.38 | 4.00 | 4.88 |
| | Piedmont, S. Dak. | 21 | 2.63 | 17.50 | 20.13 | 4.00 | 6.63 |
| | Hill City, S. Dak. | 56 | 7.00 | 13.62 | 20.62 | 4.00 | 11.00 |
| | Custer, S. Dak. | 70 | 8.75 | 14.00 | 22.75 | 4.00 | 11.75 |
| | Newcastle, Wyo. | 71 | 8.88 | 17.50 | 26.38 | 4.00 | 12.88 |
| | Whitewood, S. Dak. | 5 | .63 | 17.50 | 18.13 | 4.00 | 4.63 |
| To Newcastle, Wyo. | | | | | | | |
| From | Spearfish, S. Dak. | 66 | 8.25 | 16.87 | 25.12 | 4.00 | 12.25 |
| | Hulett, Wyo. | 83 | 10.38 | 8.00 | 18.38 | 4.00 | 14.38 |
| | Sturgis, S. Dak. | 70 | 8.75 | 17.50 | 26.25 | 4.00 | 12.75 |
| | Piedmont, S. Dak. | 86 | 10.75 | 17.50 | 28.25 | 4.00 | 14.75 |
| | Hill City, S. Dak. | 51 | 6.38 | 13.62 | 20.00 | 4.00 | 10.38 |
| | Custer, S. Dak. | 37 | 4.63 | 14.00 | 18.63 | 4.00 | 8.63 |
| | Newcastle, Wyo. | 0 | 0.00 | 17.50 | 17.50 | 4.00 | 4.00 |
| | Whitewood, S. Dak. | 71 | 8.88 | 17.50 | 26.38 | 4.00 | 12.88 |

[1] *Maps and Charts for Determining Distance in Hiway Miles, Household Carriers Bureau, 1973.*

[2] *The hauling cost assumes that a 10-unit van can be operated for $1.50 per loaded mile and one unit of sawmill residue equals 1.2 o.d. tons.*

[3] *The cost of chips at the sawmill assumes that chips are worth $17.50 per o.d. ton f.o.b. railcar in the Black Hills. Chip cost at the sawmills represents the difference between $17.50 and the handling and trucking costs to the rail sidings. Mileage and trucking costs per o.d. ton to rail sidings from sawmills without adjacent rail facilities are:*
*Spearfish, S. Dak., to Jolly Siding, S. Dak.—5 miles and $.63,*
*Hulett, Wyo., to Whitewood, S. Dak.—60 miles and $9.50,*
*Hill City, S. Dak., to Rapid City, S. Dak.—31 miles and $3.88,*
*and Custer, S. Dak., to Hermosa, S. Dak.—28 miles and $3.50.*
*Trucking costs for the Hulett sawmills includes $2.00 per ton for unloading facilities.*

educational, and public service facilities, and outdoor recreational opportunities as the communities in the Whitewood area.

Approximately 73 to 126 full-time employees would be needed, depending upon the size of the facility. The necessary professional and skilled workers for a particleboard plant could probably be attracted to either Whitewood or Newcastle.

### Manufacturing Process

The manufacturing facilities described would be capable of producing particleboard for such construction uses as floor underlayment and mobile home decking and industrial uses including furniture core, cabinets, door core, and exterior board. The board product assumed is either three-layered or graduated with fiberous fines on the faces and coarser furnish in the core. The furnish would consist of planer shavings, ring cut flakes, and refined sawdust. Formaldehyde resin and wax would be the other contents of the board.

The process in general consists of the following: all wood raw materials are received on a truck scale and a truck dump unit; green material is conveyed to outside storage and piled with a radial stacker; dry material, such as planer shavings, is stored under a roof; the truck dump would be enclosed to minimize particulate emission.

Raw material feed bins would handle approximately 4-5 hours of plant flow. Planer shavings are screened with the fines passing directly to the dryer ovens. Coarser shavings are reduced in a ring type flaker. Sawdust is screened to remove large pieces prior to refining. Either double or single disc refiners mill the sawdust into fiber-like fine particles. Green chips are also reduced in ring type flakers. Magnets on conveyors eliminate tramp metal.

Each type of material is dried separately in dryers equipped with spark detectors and fire dumps. The material is then sent to the appropriate storage bins for face or core particles through interconnecting conveyors. Two blenders are required—one for the face layers and one for the core. Prior to blending, the material is measured by either scales or by density gages. This measuring system is connected to resin pumps that assure control of the resin and wax added, based on actual wood flow. The mat is formed either by three-layer or air-felting formers. The air-felting type of former gives better board surface characteristics with mill waste raw material. The mats would be handled on a conventional caul system.

The assumed presses are designed for fast closing and a specific pressure of 700-800 pounds per square inch. The entire caul handling and pressing system should have a press cycle of 3 minutes in order to manufacture thin (1/4-inch) panels at an efficient rate. The boards are passed through a cooler and stacked or sawed and stacked, depending on the plant size. The finishing section is equipped with 5-foot-wide belt sanders and a basic trim and cutup saw, with three saws on the first section and six to seven saws on the cross-cut or second section. A small cut-to-size saw is also provided.

A basic concern of this study was the availability of energy for a plant in the Black Hills. There appears to be plenty of wood waste such as bark in the area which can be delivered to a plant at a cost less than $10 per o.d. ton. Bark at this cost would generate heat at a lower cost per Btu than coal. Natural gas is available and therefore considered as a "control" fuel to supplement the dust burners. Because of the above considerations the fuel system was designed for use of the waste generated by the plant. Any shortage in these wastes to meet fuel requirements would be made up by purchasing bark or other wood residues from other plants.

The projected boilers are designed for burning dust and bark as well as coal and will supply steam for the "dry" dryers, presses, building heat, and resin and wax heating. The "dry" dryers handling the dry shavings are heated by steam heat/air exchangers to minimize the fire hazard. The "wet" dryers for drying the green material are fueled with direct fired dust and supplemented by boiler stack gases. These dryers also have auxiliary gas burners. The sized trim from the panels is hogged and screened to proper size for the dust burners. This material is then temporarily stored before being conveyed to the metering bins of the boiler and the "wet" dryers.

It is difficult to vary the amount of heat produced by a dust burner to accommodate moisture variations in the material to be dried. Such difficulties are overcome by supplementing the basic heat load provided by the dust burner with the auxiliary gas burners. This method requires about 10-15% of the total heat to be supplied by natural gas.

Cyclones and filters would keep particulate emission within the permissible standards. Bag houses are not recommended because of excessive fire hazard. Blue haze would be kept within acceptable standards because of low dryer temperatures (600-700° F) and keeping the salt content of the resin to a minimum. The effluent resulting from washing the blender and the containers and pipe lines to remove resin and wax will be treated in a lagoon.

The building would probably be a single-story steel type on a concrete slab, with insulated roof and wall panels. Fire protection would include building sprinklers, fire hydrants, and a fire pond or tank with pumping equipment.

### Manufacturing Requirements and Costs

The total unit costs of manufacturing particleboard in the Black Hills were assessed using discounted cash flow analysis (DCFA) with the aid of a computer program (Harpole 1978). These unit production costs were computed in terms of per unit revenue required, f.o.b. the particleboard plant, to cover all operating costs, capital recovery requirements (depreciation), and return on the investment. The type of return on invest-

ment used in this study was internal rate of return (IRR). This value represents a single interest rate return to total investment where total investment is the sum of the investment requirements for facilities and working capital. The IRR is the interest earnings realized as after-tax profit in DCFA. This method of evaluating capital investments differs from the return on original investment method (ROI) where the average annual income after taxes and depreciation is divided by the original capital outlay.

Facilities costs and operating requirements and costs were projected by Columbia Engineering International Ltd. under contract. Estimates of wood costs were developed by the Forest Service. Figures B-1, B-2, and B-3, are layouts for three facilities with annual capacities of 33.5, 67.0, and 100.0 MM ft², 3/4-inch basis. All operating costs and revenue were assumed to increase at the rate of 5% per year.

### Capital Requirements and Costs

Total capital requirements, including both facilities cost and working capital, ranged from $12,364,000 to $22,790,000 depending on the size and type of plant. Capital requirements in 1978 for facilities with annual production of 33.5, 67.0, and 100.0 MM ft² are summarized in tables B-1 through B-5. The press sizes considered for the 33.5-MM ft² facilities were 5- × 9-foot, 16-opening and 5- × 18-foot, 8-opening. The press size for the 67.0-MM ft² facility was 5- × 18-foot, 16-opening, and for the 100.0 MM ft² facility was 5- × 18-foot, 24-opening. Major components of the facilities cost were building and site development, equipment and installation, engineering and construction management, carrying interest and local sales tax on construction, pre-startup expenses, and a contingency allowance. The working capital needed was estimated to be equal to 2 months (16.7%) of annual manufacturing cost. The latter included raw material cost, process labor, administrative overhead, and factory overhead. Depending on size and type of plant, building and site development costs ranged from $1,760,000 to $3,572,000; equipment plus installation costs from $7,724,000 to $13,943,000 (tables B-2, B-3, and B-4). Engineering and construction management and the contingency allowance together are approximately 15% of the building and site development, equipment, and installation costs. Construction carrying interest and local sales tax together were about 7% of the total facilities costs. Pre-startup expenses include salaries of key plant operating personnel hired prior to plant startup to ensure the fastest possible build-up in plant output and sales (table B-5).

### Operating Requirements and Costs

Operating requirements and costs are summarized in tables B-6 through B-10. The wood raw materials considered for the different sized facilities were:

| Plant size | Wood raw material mix |
|---|---|
| *MM ft² per year* | |
| 33.5 | 75% Day shavings<br>25% Green sawdust |
| | 50% Dry shavings<br>50% Green sawdust |
| 67.0 | 46% Dry shavings<br>54% Green sawdust |
| 100.0 | 31% Shavings<br>43% Green sawdust<br>26% Green chips |

Depending on the type and size of plant, the annual volume of dry shavings required would range from 26,663 to 49,290 o.d. tons, green sawdust from 13,316 to 68,370 o.d. tons, and green chips from 0 to 41,340 o.d. tons (table B-6). The average cost per o.d. ton of wood raw material delivered to plants at Whitewood and Newcastle ranged from $5.67 to $13.37, depending on the plant capacity and location and the wood raw material mix (table B-7).

The annual volume of resin would range from 4,003 tons for the 33.5-MM ft² plant to 11,950 tons for the 100-MM ft² plant, wax from 536 to 1,600 tons, and electricity from 14,658 to 26,241 MWh (table B-6). Energy requirements in the form of process steam for presses, "dry" dryers, and building heat and hot stack gases for the "wet" dryer are given in table B-8. Supply factors—dry trim and dust, green bark, and hot stack gas are also listed in table B-8. Natural gas would be used only if the bark is excessively wet because of rain or some other cause.

The estimated costs of resin, wax, electric power and fuel during 1978 were as follows:

| Raw material | Cost |
|---|---|
| | *dollars* |
| Resin (per pound) | .13 |
| Wax (per pound) | .14 |
| Electric power (per kWh) | .02 |
| Fuel | |
| Dry fine and trim (per o.d. ton) | 0 |
| Wet bark (per o.d. ton) | 10.00 |
| Natural gas (per M ft³) | 1.69 |

The total number of full-time jobs would vary from 73 to 126 depending on the plant capacity (table B-9). Employment costs (3 shifts, 7 days per week) were based on a $16,000 cost per average man-year, including fringe benefits. The manning requirement are assumed to be at 77% of full requirements during the first year and at full level thereafter. Production is assumed to be at 46.7% during the first year, 98.8% during the second year, and 100.0% thereafter. The

wages of the direct manufacturing employees are included as processing labor costs, maintenance and repair employees as factory overhead, and administration and sales employees as administrative overhead in the DCFA (table B-10). Factory overhead also includes costs of maintenance supplies and administrative overhead also the costs of office maintenance, travel expense, insurance, and local property and sale taxes.

Assumptions used in calculating break-even production costs were:

1. Investment tax credit—10% of the cost of processing equipment.
2. Selling cost—10% of the selling price to cover 5% sales commission, 2% cash discount, and a 3% bad debt allowance.
3. Tax rate—48% of taxable income for federal corporate income taxes. South Dakota and Wyoming do not have corporate income taxes.
4. Inflation rate—5% per year increase in costs and revenue.
5. Rate of return on investment—15% internal rate of return (15% IRR).
6. Economic life—10 years.

The method of depreciating capital assets is shown for the 100.0 MM ft² per year facility (table B-11). Land was not depreciated. Site preparation, buildings, mobile equipment, and miscellaneous were depreciated by the straight line method. Process machinery was depreciated using the double declining method for the first 5 years and the straight line method for the second 5 years.

The break-even unit production costs or plant prices ranged from $173.46 per M ft² for the 100.0 MM ft² (5- × 18-foot, 24-opening) facility to $241.19 per M ft² for the 33.5-MM ft² (5- × 18-foot, 8-opening) facility using 50% dry shavings and 50% green sawdust as the furnish (table 4). The itemized production costs in this table are expressed in terms of 1978 unit prices and are calculated from data of the DCFA computer program. For example, the proportion of the total variable cost to total sales over the 10-year period is 0.5531 (table B-12). This proportion value multiplied by the unit price for 1978 equals the total variable cost in table 4 for the 100.0 MM ft² facility. All itemized production costs in this table except that for raw materials were higher for the smaller than the larger plants. The higher raw material cost at the 100.0 MM ft² facility included higher cost pulp chips in the furnish because of insufficient supply of sawdust and shavings.

Year-end values are also projected by the DCFA program. These include unit sales, gross sales, gross revenue, raw material cost, administrative overhead, factory overhead, total fixed cost, working capital investment, depreciation, after-tax profit, after-tax earnings, after-tax net cash flow, and accumulated net cash flow (table B-12).

The plant selling price or total manufacturing cost, including internal rate of return, required for 6 levels of profitability—0, 5, 10, 15, 20, and 25% internal rate of return—was determined (table 5). The effects of both plant size and the market price upon profit become readily apparent. The break-even price at 0% internal rate of return indicates the survival capacity of the plant during periods of low market prices.

### Feasibility Assessment

The assessment of feasibility assumes that the market price in the area served by a plant in the Black Hills will be established primarily by West Coast production. The product value at a Black Hills plant thus could be approximated as the West Coast price plus the freight advantage to the market areas. The average rail freight advantage of a Black Hills plant would be

Table 4.—Estimated production cost (dollars per M ft², 3/4-inch basis) at 15% internal rate of return for different particleboard facilities in the Black Hills, 1978

| | Plant capacity (MM ft² per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | *Wood raw material* | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| | *Press size* | | | | | |
| Cost category | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Raw materials | 60.92 | 60.93 | 60.96 | 60.96 | 61.09 | 63.98 |
| Processing labor | 24.51 | 24.51 | 24.51 | 24.51 | 18.38 | 14.61 |
| Selling expense | 22.89 | 23.88 | 23.14 | 24.12 | 18.72 | 17.35 |
| Total variable costs | 108.32 | 109.32 | 108.61 | 109.59 | 98.19 | 95.94 |
| Fixed manufacturing cost | 27.62 | 27.73 | 27.60 | 27.64 | 21.27 | 19.22 |
| Depreciation | 24.02 | 25.96 | 24.75 | 26.68 | 17.16 | 14.49 |
| Taxes (Federal income) | 31.15 | 34.32 | 31.83 | 34.99 | 22.91 | 19.87 |
| After tax profit (15% IRR) | 37.74 | 41.44 | 38.60 | 42.29 | 27.68 | 23.94 |
| TOTAL COST/M ft² | 228.85 | 238.77 | 231.19 | 241.19 | 187.21 | 173.46 |

about \$30.00 per M ft², to Chicago, Des Moines, Kansas City, Milwaukee, Minneapolis, and Omaha (table A-1).

The West Coast quarterly average price for 3/4-inch industrial board ranged from \$100 to \$183 f.o.b. plant from March 1976 through December 1978. An f.o.b.-plant value in the Black Hills would have ranged from \$130 to \$213 assuming a \$30 freight advantage for 3/4-inch thickness (fig. 4). The break-even total production costs (0% internal rate of return) for three different size facilities are shown by the three straight lines. Only the 67.0 and 100.0 MM ft² facilities would have yielded a positive rate of return over the entire three year period. The 33.5-MM ft² facility was profitable only during the latter portion of the period. The 1978 production costs were discounted 5% annually in estimating the other yearly production costs, reflecting inflation.

West Coast quarterly average price for 5/8-inch underlayment ranged from \$45 to \$175 f.o.b. plant from January 1973 through December 1978. An f.o.b. plant value in the Black Hills would have ranged from \$70 to \$200, assuming a \$25 freight advantage (fig. 5). Again, total production costs with 0% internal rate of return for three different size facilities are shown by the straight lines. Both the 67.0- and 100.0-MM ft² facilities would have shown minimum profits or losses from June 1974 to March 1977. The 33.5-MM ft² facility would have shown a consistent loss during the period. All three facilities showed profitability before and after this period. The 1978 production costs were discounted 5% annually to estimate the other yearly production cost, reflecting inflation.

The sensitivity of total unit production cost to changes in various operational costs and to reductions in plant output is important. The cost of adhesive and wax would probably be similar at most locations except for transportation to the plant. The wood, energy,

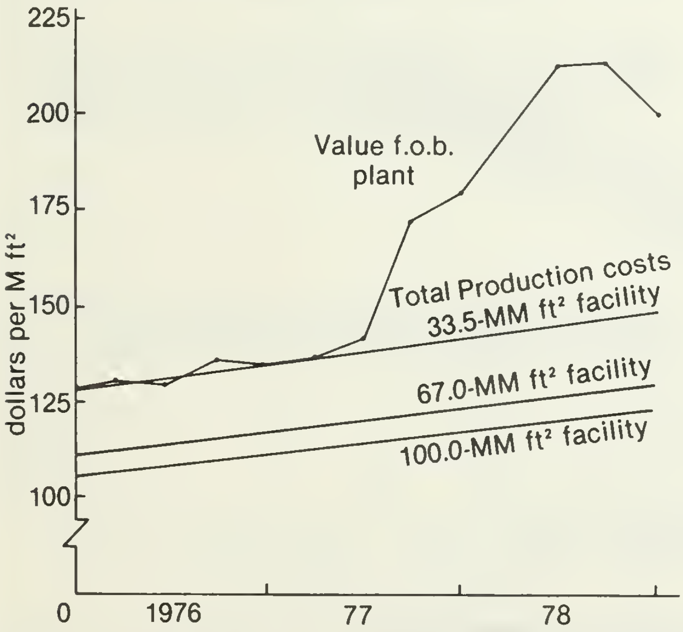



**Figure 4.—Comparison of value f.o.b. plant with total production costs at 0% internal rate of return for 3/4-inch industrial particleboard produced in facilities of three different sizes.**

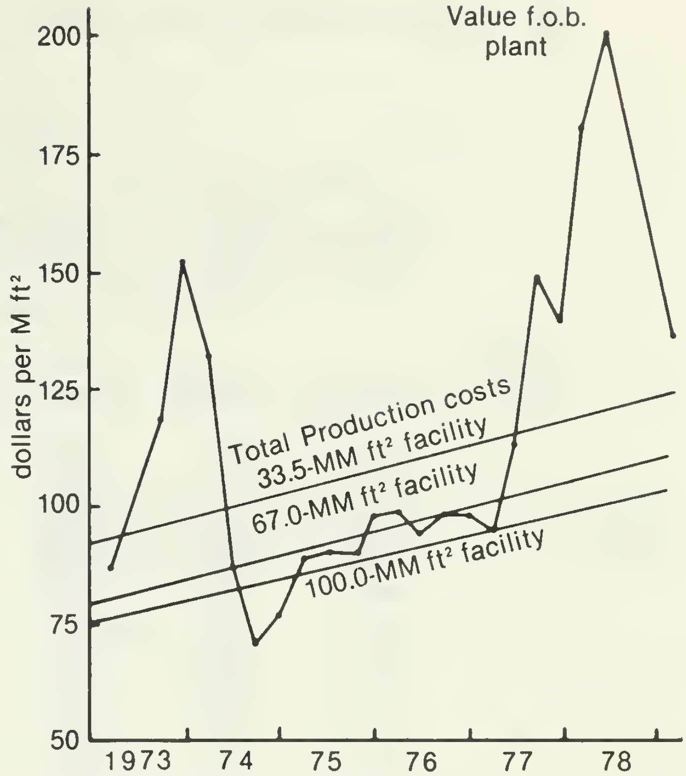



**Figure 5.—Comparison of value f.o.b. plant with total production costs at 0% internal rate of return for 5/8-inch underlayment particleboard produced in facilities of three different sizes.**

and salary costs, however, are more dependent on local supply and demand and would tend to vary more depending on plant location. Total production costs are not only affected directly by changes in the operational costs but also indirectly through associated changes in selling expense, after tax profit, taxes, and working capital. Sensitivity analyses indicated that total cost in dollars per million square feet, 3/4-inch basis, would be increased by:

1. \$1.85 for each \$1.00 per o.d. ton increase of wood cost for both the 67.0-MM ft² and 100.0-MM ft² facilities (fig. 6).
2. \$4.05 for the 67.0-MM ft² and \$3.05 for the 100-MM ft² facility for each 1 cent increase per kWh in electricity cost (fig. 7).
3. \$1.20 for the 67.0-MM ft² and \$1.63 for the 100-MM ft² facility for each \$1.00/thousand cubic feet increase of natural gas cost (fig. 8).
4. \$0.13 for the 67.0-MM ft² and \$0.16 for the 100-MM ft² facility for each \$1.00 per o.d. ton increase of bark cost (fig. 9).
5. \$1.93 for the 67.0-MM ft² and \$1.56 for the 100-MM ft² facility for each \$1000 per year increase of average salary including benefits (fig. 10).

It is apparent from the figures that total unit production costs changed linearly with the costs of the above resources. However, the unit production costs increased at an increasing rate with the reduction of plant output because of increasing unit fixed costs (fig. 11).

Table 5.—Estimated production cost (dollars per M $ft^2$, 3/4-inch basis) including internal rate of return or plant selling price[1] for different particleboard plants in the Black Hills operating at six levels of profitability or internal rates of return, 1978

| Internal rate of return (percent) | Plant capacity (MM $ft^2$ per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | Wood raw material | | | | | |
| | 75% Dry shavings, 25% Green sawdust | | 50% Dry shavings, 50% Green sawdust | | 46% Dry shavings, 54% Green sawdust | 31% Dry shavings, 43% Green sawdust, 26% Green chips |
| | Press size | | | | | |
| | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| 0 | [2]148.22 | 150.21 | 148.90 | 150.82 | 128.08 | 122.31 |
| | 123.52 | 125.18 | 124.08 | 125.68 | 106.73 | 101.93 |
| 5 | 171.68 | 176.00 | 172.88 | 177.12 | 145.33 | 137.28 |
| | 143.07 | 146.67 | 144.07 | 147.60 | 121.11 | 114.40 |
| 10 | 198.56 | 205.53 | 200.38 | 207.25 | 165.05 | 154.33 |
| | 165.47 | 171.28 | 166.98 | 172.71 | 137.54 | 128.61 |
| 15 | 228.85 | 238.77 | 231.39 | 241.19 | 187.21 | 173.46 |
| | 190.71 | 198.98 | 192.83 | 200.99 | 156.01 | 144.55 |
| 20 | 262.44 | 275.62 | 265.78 | 278.83 | 211.73 | 194.60 |
| | 218.70 | 229.68 | 221.48 | 232.36 | 176.44 | 162.17 |
| 25 | 299.14 | 315.86 | 303.37 | 319.95 | 238.48 | 217.63 |
| | 249.28 | 263.22 | 252.81 | 266.63 | 198.73 | 181.36 |

[1] *When internal rate of return is included in production costs, total production costs and plant selling price are equal.*
[2] *Upper costs are for 3/4-inch and lower for 5/8-inch thickness. The cost for 5/8-inch was estimated to be 83.3% of that for 3/4-inch, assuming costs to be proportional to thickness.*

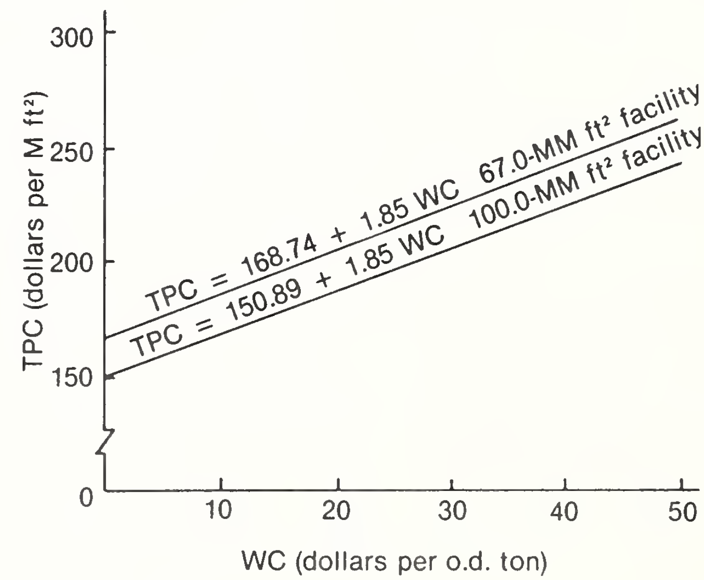



**Figure 6.—The effect of wood cost (WC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15 % IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.**

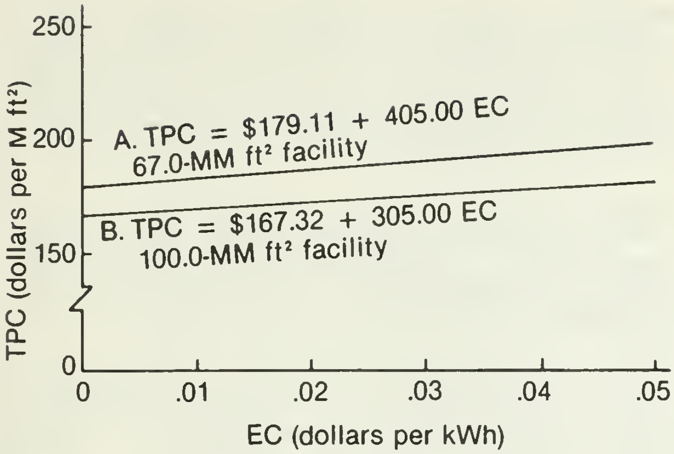



Figure 7.—Effects of electricity cost (EC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15 % IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

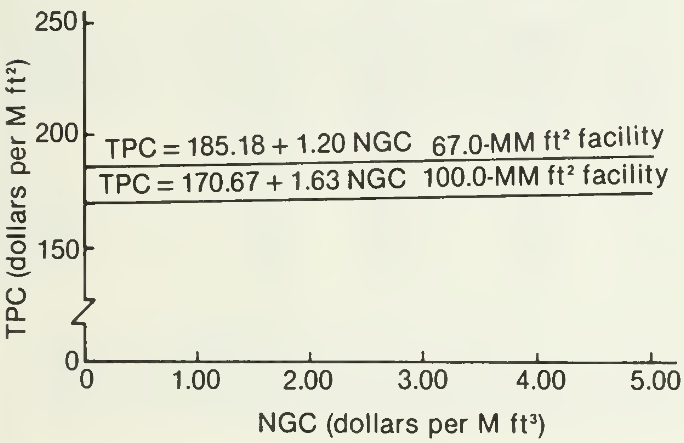



Figure 8.—Effects of natural gas cost (NGC) on total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

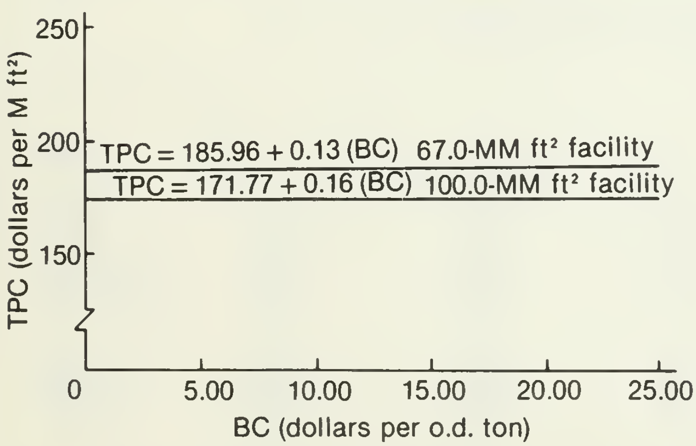



Figure 9.—Effect of bark cost (BC) or total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

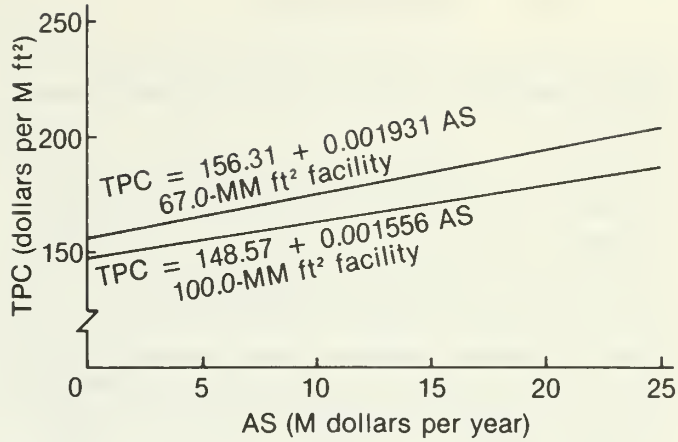



Figure 10—.Effect of average salary including benefits (AS) on total production cost (TPC) including selling expense, taxes, and cost of capital (15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

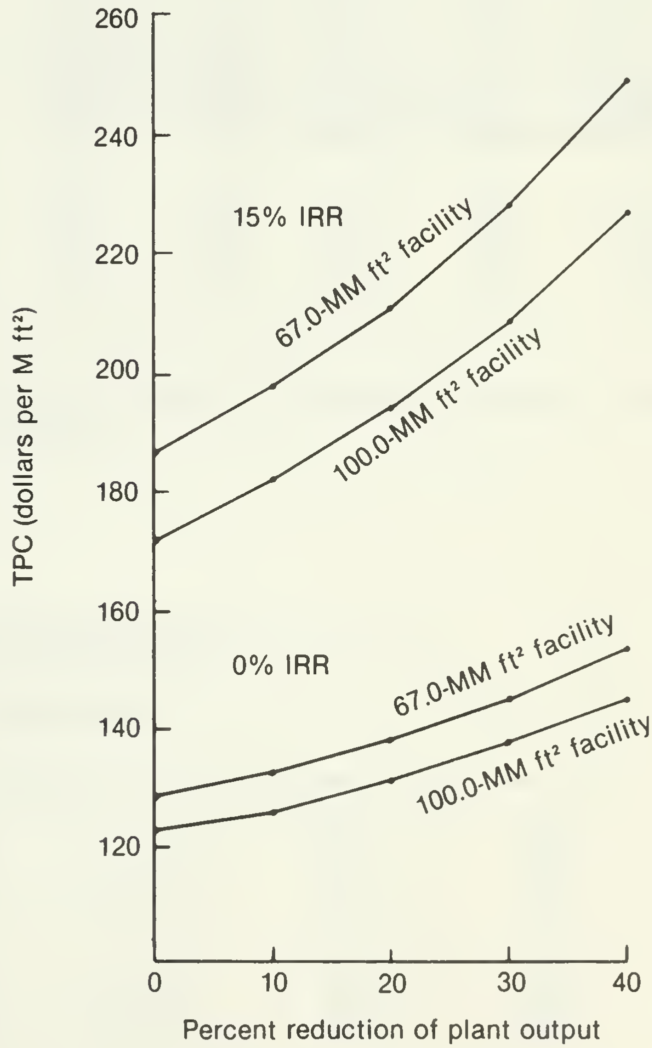



Figure 11.—Effects of reduced plant output on total production cost (TPC) with varying return to capital (0% and 15% IRR) for 3/4-inch particleboard manufactured at two facilities with different annual capacities in the Black Hills.

## Literature Cited


Applefield, Milton. 1972. Regulations affecting wood use in building construction. Forest Products Journal 22(4):12-16.

Dickerhoof, H. Edward, and David B. McKeever. 1979. Particleboard, medium-density fiberboard and Mende process board plants in the United States—capacity, production, and raw material trends, 1956-1976. USDA Forest Service Resource Bulletin, FPL-6, 18 p. Forest Products Laboratory, Madison, Wisc.

Harpole, George B. 1978. A cash flow computer program to analyze investment opportunities in wood manufacturing. USDA Forest Service Research Paper FPL 305, 24 p. Forest Products Laboratory, Madison, Wisc.

Landt, E. F., and Woodfin R. O., Jr. 1964. Sawmills and logging residues from ponderosa pine trees in the Black Hills. USDA Forest Service Research Note RM-23, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Markstrom, Donald C., and Vern P. Yerkes. 1972. Specific gravity variation with height in Black Hills ponderosa pine. USDA Forest Service Research Note RM-213. 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Markstrom, Donald C., William F. Lehmann, and J. Dobbin McNatt. 1976. Technical feasibility of producing particleboard from Black Hills ponderosa pine. USDA Forest Service Research Paper RM-173. 10 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Setzer, Theodore S. 1973. Logging residues on harvesting operations, Western South Dakota, Wyoming, Utah, and Colorado. USDA Forest Service Research Paper INT-135, 13 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

South Dakota Department of Game, Fish and Parks. 1974. South Dakota forest products manufacturing directory. 31 p. South Dakota Department of Game, Fish and Parks, Division of Forestry. Pierre.

U.S. Department of Agriculture, Forest Service. 1977. The demand and price situation for forest products 1976-1977. Miscellaneous Publication 1357. 95 p. Washington, D.C.

U.S. Department of Agriculture, Forest Service. 1979. An assessment of forest and range land in the United States. Unnumbered publication. 556 p. Washington, D.C.

## Appendix A

### Tables and Figures on Marketing of Particleboard

Table A-1.—Railroad freight rates (dollars per M $ft^2$, 3/4-in basis) for particleboard from production to market locations[1,2,3]

| Market | Production locations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Whitewood, S. Dak. | Newcastle, Wyo. | Portland, Oreg. | Missoula, Mont. | Gaylord, Mich. | Crossett, Ark. | Birmingham, Ala. | Charlotte, N. C. | Diboll, Tex. |
| Boston | 87.11 | 88.26 | 87.11 | 84.81 | 40.54 | 83.95 | 54.34 | 41.69 | 87.98 |
| Chicago | 41.11 | 42.26 | 75.33 | 72.74 | 23.29 | 41.98 | 35.94 | 41.98 | 52.90 |
| Columbus | 61.81 | 62.96 | 85.96 | 82.51 | 25.59 | 53.48 | 33.93 | 33.64 | 64.40 |
| Denver | 24.73 | 21.56 | 41.98 | 34.21 | 74.75 | 56.64 | 58.65 | 69.00 | 55.49 |
| Des Moines | 31.34 | 34.79 | 73.31 | 69.58 | 42.26 | 44.85 | 41.40 | 52.61 | 48.01 |
| Detroit | 61.54 | 62.68 | 85.10 | 81.65 | 18.69 | 59.51 | 38.24 | 38.81 | 70.44 |
| Kansas City | 35.94 | 34.79 | 68.71 | 65.55 | 50.31 | 35.94 | 38.53 | 52.33 | 39.96 |
| Milwaukee | 40.25 | 41.69 | 75.33 | 72.74 | 19.55 | 44.85 | 38.24 | 44.56 | 56.93 |
| Minneapolis | 29.04 | 35.65 | 68.71 | 65.55 | 39.96 | 52.61 | 48.59 | 57.21 | 59.23 |
| New York | 83.95 | 85.10 | 87.11 | 84.81 | 38.81 | 79.93 | 46.29 | 34.21 | 83.95 |
| Omaha | 27.31 | 27.31 | 68.71 | 65.55 | 50.31 | 44.85 | 44.85 | 56.64 | 47.73 |
| Philadelphia | 81.08 | 82.23 | 87.11 | 84.81 | 38.81 | 79.06 | 43.99 | 32.20 | 82.51 |
| St. Louis | 41.69 | 41.69 | 74.46 | 70.73 | 32.78 | 29.90 | 23.00 | 29.04 | 40.83 |
| Washington, D.C. | 79.64 | 80.79 | 87.11 | 84.81 | 37.95 | 73.60 | 26.45 | 18.69 | 79.93 |
| Wichita | 36.80 | 34.79 | 68.71 | 65.55 | 60.38 | 35.94 | 44.85 | 56.64 | 35.94 |

[1]*All values are based on 3/4-in thickness, 46 lb/ft³ or 2,875 lb/M ft².*
[2]*70,000-pound shipments.*
[3]*Freight rates were compiled by Mountain States Commerce and Traffice Services, Inc., Denver, Colo.—November 1977. These rates have been increased numerous times since then but have remained in about the same ratio.*

Table A-2.—Motor common carrier truckload freight rates (dollars per M $ft^2$, 3/4-in, basis) for particleboard from production to market locations[1,2,3]

| Market locations | Production locations | | | | | |
|---|---|---|---|---|---|---|
| | Whitewood, S. Dak. | Newcastle, Wyo. | Portland, Oreg. | Missoula, Mont. | Crossett, Ark. | Diboll, Tex. |
| Chicago | 46.58 | 43.41 | 82.51 | 72.45 | 44.56 | 52.04 |
| Denver | 24.44 | 20.41 | 54.34 | 43.70 | 60.95 | 52.04 |
| Des Moines | 34.79 | 34.79 | 81.65 | 71.30 | 41.11 | 43.99 |
| Kansas City | 36.80 | 38.24 | 91.43 | 70.15 | 30.48 | 33.35 |
| Minneapolis | 32.49 | 34.21 | 78.78 | 64.40 | 56.35 | 58.08 |
| Omaha | 31.91 | 32.49 | 82.51 | 69.00 | 46.86 | 41.98 |
| St. Louis | 49.16 | 46.29 | 82.51 | 72.45 | 28.45 | 37.09 |
| Wichita | 35.94 | 35.94 | 84.53 | 72.45 | 34.21 | 30.48 |

[1]*All values are based on 3/4-in thickness, 46 lb/ft³ or 2,875 lb/M ft².*
[2]*All rates are commodity rate.*
[3]*Freight rates were compiled by Mountain States Commerce and Traffic Services, Inc., Denver, Colorado—November 1977. These rates have been increased numerous times since then but have remained in about the same ratio.*

Table A-3.—North Central United States estimated consumption of particleboard, 1965-1990
(MM ft², 3/4-in basis)[1]

| End use | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|---|---|
| Construction | | | | | | |
| Residential | | | | | | |
| 1 and 2 family | 27.1 | 56.3 | 85.0 | 136.5 | 187.3 | 228.8 |
| Multi-family | 8.4 | 8.9 | 14.3 | 15.1 | 13.5 | 12.7 |
| Subtotal residential | 35.5 | 65.2 | 99.3 | 151.6 | 200.8 | 241.5 |
| Nonresidential | 9.5 | 14.0 | 12.7 | 21.2 | 26.5 | 33.1 |
| Repairs and remodeling | 26.6 | 48.5 | 66.5 | 80.6 | 115.0 | 142.1 |
| Subtotal construction | 71.6 | 127.7 | 178.5 | 253.4 | 342.3 | 416.7 |
| Industrial uses | | | | | | |
| Furniture and fixtures | | | | | | |
| Household furniture (wood) | 39.2 | 74.7 | 125.3 | 217.5 | 316.5 | 455.7 |
| Household furniture (metal) | 10.5 | 18.7 | 24.3 | 36.9 | 47.7 | 58.8 |
| Office furniture (wood) | 1.2 | 4.1 | 8.0 | 13.0 | 19.0 | 26.3 |
| Office furniture (metal) | .8 | 2.3 | 4.5 | 8.6 | 12.4 | 16.4 |
| Public building furniture | 7.4 | 13.8 | 22.1 | 35.1 | 45.8 | 59.2 |
| Partitions and fixtures | 24.4 | 45.4 | 74.4 | 128.5 | 187.2 | 269.1 |
| Misc. furniture and fixtures | 2.9 | 4.6 | 7.4 | 11.4 | 16.2 | 23.6 |
| Subtotal furniture and fixtures | 86.4 | 163.6 | 266.0 | 451.0 | 644.8 | 909.1 |
| Mobile homes | 4.1 | 65.0 | 96.3 | 103.8 | 98.9 | 103.8 |
| Recreation vehicles | 0.9 | 4.0 | 2.3 | 8.7 | 14.1 | 20.4 |
| Modular homes | 0.0 | 6.3 | 21.8 | 45.1 | 66.3 | 92.1 |
| General manufacturing | 16.6 | 23.3 | 41.8 | 74.4 | 113.2 | 156.8 |
| Subtotal industrial | 108.0 | 262.2 | 428.2 | 683.0 | 937.3 | 1282.2 |
| Unknown[2] | 10.6 | 23.4 | 36.4 | 56.3 | 76.8 | 101.5 |
| TOTAL CONSUMPTION | 190.2 | 413.3 | 643.1 | 992.7 | 1356.4 | 1800.4 |

[1] *The estimated proportion of the national particleboard consumption assigned to the north central region is based on the following percentages: single family homes, 25%; multi-family homes, 27%; nonresidential construction, 25%; repairs and remodeling, 25%; wood household furniture, 20%; metal household furniture, 25%; wood office furniture, 27%; metal office furniture, 53%; public building furniture, 43%; partitions and fixtures, 39%; miscellaneous furniture and fixtures, 20%; mobile homes, 29%; recreation vehicles, 39%; modular homes, 41%; and general manufacturing, 37%.*

[2] *Assumed to be 6% of the construction and industrial uses.*

Table A-4.—United States estimated consumption of particleboard, 1965-1990 (MM ft², 3/4-in basis)[1]

| End use | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|---|---|
| Construction | | | | | | |
| Residential | | | | | | |
| 1 and 2 family | 108.5 | 225.0 | 340.0 | 546.0 | 749.0 | 915.0 |
| Multi-family | 31.2 | 33.0 | 53.0 | 56.0 | 50.0 | 47.0 |
| Subtotal residential | 139.7 | 258.0 | 393.0 | 602.0 | 799.0 | 962.0 |
| Nonresidential | 38.0 | 55.9 | 50.8 | 84.9 | 106.0 | 132.2 |
| Repairs and remodeling | 106.5 | 193.8 | 266.2 | 322.6 | 460.1 | 568.3 |
| Subtotal construction | 284.2 | 507.7 | 710.0 | 1009.5 | 1365.1 | 1662.5 |
| Industrial uses | | | | | | |
| Furniture and fixtures | | | | | | |
| Household furniture (wood)[1] | 196.0 | 373.6 | 626.5 | 1087.7 | 1582.6 | 2278.5 |
| Household furniture (metal) | 41.8 | 74.8 | 97.0 | 147.5 | 190.8 | 235.1 |
| Office furniture (wood) | 4.5 | 15.0 | 29.7 | 48.0 | 70.3 | 97.3 |
| Office furniture (metal) | 1.5 | 4.4 | 8.4 | 16.3 | 23.4 | 31.0 |
| Public building furniture | 17.1 | 32.0 | 51.3 | 81.6 | 106.5 | 137.6 |
| Partitions and fixtures | 62.5 | 116.3 | 190.8 | 329.6 | 480.1 | 689.9 |
| Misc. furniture and fixtures | 14.5 | 22.8 | 37.2 | 57.1 | 80.8 | 117.9 |
| Subtotal furniture and fixtures | 337.9 | 638.9 | 1040.9 | 1767.8 | 2534.5 | 3587.3 |
| Mobile homes | 14.2 | 224.0 | 332.0 | 358.0 | 341.0 | 358.0 |
| Recreation vehicles | 2.2 | 10.3 | 6.0 | 22.4 | 36.1 | 52.3 |
| Modular homes | 0.0 | 15.3 | 53.2 | 110.0 | 161.6 | 224.6 |
| General manufacturing | 45.0 | 63.0 | 113.0 | 201.0 | 306.0 | 423.9 |
| Subtotal industrial | 399.3 | 951.5 | 1545.1 | 2459.2 | 3379.2 | 4646.1 |
| Unknown[2] | 40.4 | 87.6 | 135.3 | 208.1 | 284.7 | 376.7 |
| TOTAL CONSUMPTION | 723.9 | 1546.8 | [3]2390.4 | 3676.8 | 5029.0 | 6685.3 |

[1]*This classification includes wood kitchen cabinets and wood television and radio cabinets.*
[2]*Assumed to be 6% of the construction and industrial uses.*
[3]*Estimated 1975 particleboard production is 2,538.9 MM ft² (Current Industrial Reports 1975).*

Table A-5.—Estimated new productions (M units), particleboard consumption per unit (ft²) and national consumption (MM ft², 3/4-in basis) of particleboard for one- and two-family homes to 1990

| Year | New production[1] | Particleboard used per unit[1] | Total consumption |
|---|---|---|---|
| 1970 | 900 | 250 + 5.3% per year | 225 |
| 1975 | 1050 | 324 + 5.3% per year | 340 |
| 1980 | 1300 | 420 + 3.5% per year | 546 |
| 1985 | 1500 | 499 + 3.5% per year | 749 |
| 1990 | 1550 | 590 | 915 |

[1]*U.S. Department of Agriculture, Forest Service (1973). The outlook for timber in the United States. Forest Resource Report 20. 367 p. Washington, D.C.*

Table A-6.—Estimated deflated value of shipments (MM dollars), particleboard consumption per dollar ($ft^2$), and national consumption (MM $ft^2$, 3/4-in basis) of particleboard for wood household furniture to 1990[1]

| Year | Value of shipments[2] | Particleboard used per dollar | Total consumption |
|---|---|---|---|
| 1958 | 1382.2 | .036 + 10.4% per year | [3]49.5 |
| 1963 | 1897.9 | .059 + 21.4% per year | [4]112.7 |
| 1965 | 2250.6 | .087 + 11.6% per year | [5]196.0 |
| 1970 | 2474.0 | .151 + 11.6% per year | 373.6 |
| 1972 | 3645.4 | .188 + 3.0% per year | [6]685.1 |
| 1975 | 3056.2 | .205 + 3.0% per year | 626.5 |
| 1980 | 4570.2 | .238 + 3.0% per year | 1,087.7 |
| 1985 | 5734.2 | .276 + 3.0% per year | 1,582.6 |
| 1990 | 7120.2 | .320 | 2,278.5 |

[1]*Includes wood television and radio cabinets—SIC 2517; and wood kitchen cabinets—SIC 2434.*

[2]*Calculated on basis of data from:*

*Industry Profiles 1958-1969. SIC 2511, page 83, U.S. Department of Commerce.*

*Annual Survey of Manufacturers 1970-1971. U.S. Department of Commerce, Bureau of the Census.*

*Annual Survey of Manufacturers 1973. General Statistics for Industry Groups and Industries, M73(AS)-1, U.S. Department of Commerce, Bureau of the Census.*

*Annual Survey of Manufacturers 1974. General Statistics for Industry Groups and Industries, (Including Supplemental Labor Costs) M74(AS)-1, U.S. Department of Commerce, Bureau of the Census.*

*Annual Survey of Manufacturers 1975. Value of Product Shipments, M75(AS-2), U.S. Department of Commerce, Bureau of the Census.*

*GNP Values and Implicit Price Deflators, table B-1, page 171; and table B-3, page 174 of the Economic Report of the President, January 1976.*

*Wholesale Price Index for Furniture and Household Durables, table B-47, page 226, Economic Report of the President, January 1976.*

*Projected GNP and Implicit Price Deflator Values for 1980, 1985, and 1990 from Predicast, January 1977, Predicast, Inc.*

[3]*U.S. Department of Commerce. 1966. Industry Statistics. 1963 Census of Manufacturers MC 63(2)-25A.*

[4]*U.S. Department of Commerce. 1971. Summary and Subject Statistics. 1967 Census of Manufacturers.*

[5]*U.S. Department of Agriculture, Forest Service 1969. Wood Used in Manufacturing Industries 1965. Statistical Bulletin No. 440, 91 p.*

[6]*U.S. Department of Commerce. 1976. Industry Statistics. 1972 Census of Manufacturers.*

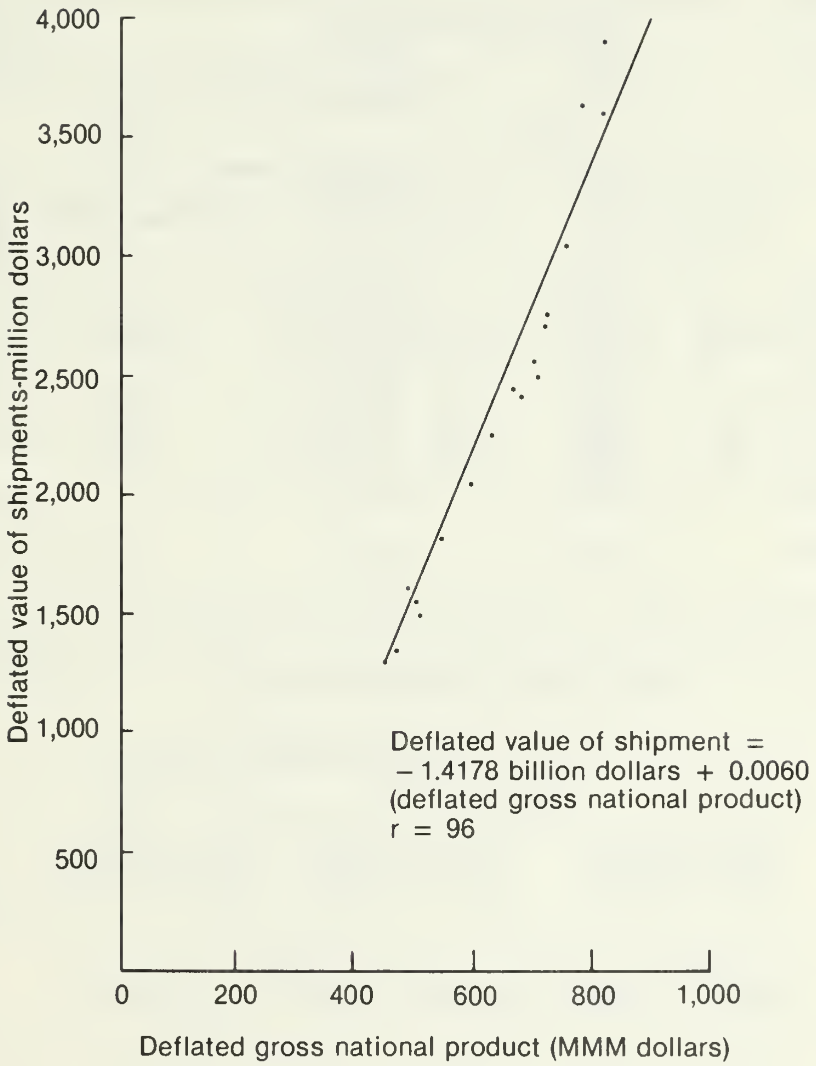



Figure A-1.—Scatter diagram and linear regression of deflated values for shipments of wood household furniture to deflated gross national product.

# Appendix B

## Tables and Figures on Manufacturing of Particleboard

Table B-1.—Estimated capital requirements (M dollars) for particleboard plants of different capacities in the Black Hills (1978)

| Cost category | Plant capacity (MM ft² per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | *Wood raw material* | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| | *Press size* | | | | | |
| | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Facilities cost | 11,955 | 13,148 | 12,278 | 13,470 | 17,160 | 21,803 |
| Working capital | 409 | 409 | 409 | 409 | 700 | 987 |
| Total capital requirements | 12,364 | 13,557 | 12,687 | 13,879 | 17,860 | 22,790 |

Table B-2.—Estimated facilities costs (M dollars) including pre-startup expenses for particleboard plants of different capacities in the Black Hills (1978)

| Cost category | Plant capacity (MM ft² per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | *Wood raw material* | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| | *Press size* | | | | | |
| | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Building and site development | 1,760 | 2,202 | 1,760 | 2,202 | 2,652 | 3,572 |
| Equipment and installation | 7,724 | 8,247 | 7,967 | 8,490 | 11,041 | 13,943 |
| Engineering and construction management | 755 | 827 | 786 | 858 | 1,070 | 1,325 |
| Contingency allowance | 661 | 724 | 687 | 750 | 937 | 1,160 |
| Construction carrying interest and local sales tax on construction items | 857 | 950 | 880 | 972 | 1,237 | 1,580 |
| Pre-startup expenses | 198 | 198 | 198 | 198 | 223 | 223 |
| Total | 11,955 | 13,148 | 12,278 | 13,470 | 17,160 | 21,803 |

Table B-3.—Estimated building, structures, site preparation, and land costs (dollars) for particleboard plants of different capacities in the Black Hills (1978)

| | Plant capacity (MM ft² per year) | | | |
|---|---|---|---|---|
| | 33.5 | | 67.0 | 100.0 |
| | Press size | | | |
| Cost category | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Building area - square feet | | | | |
| Raw material storage | 14,000 | 14,000 | 16,000 | 20,000 |
| Milling, drying, boiler | 13,000 | 13,000 | 14,000 | 30,000 |
| Blending and press line | 30,000 | 40,000 | 40,000 | 45,000 |
| Finishing and warehouse | 31,000 | 45,000 | 62,000 | 87,000 |
| Miscellaneous shops, offices, etc. | 2,000 | 2,000 | 3,000 | 3,000 |
| Total building area | 90,000 | 114,000 | 135,000 | 185,000 |
| Building costs - dollars | | | | |
| Materials and labor[1] | 1,430,000 | 1,802,000 | 2,137,000 | 2,912,000 |
| Average cost per square foot | 15.89 | 15.81 | 15.83 | 15.74 |
| Site development - dollars | | | | |
| Land purchase[2] | 40,000 | 50,000 | 60,000 | 80,000 |
| Site clearing and grading | 50,000 | 60,000 | 85,000 | 100,000 |
| Rail spur | 20,000 | 30,000 | 40,000 | 60,000 |
| Sewers and drainage | 30,000 | 35,000 | 45,000 | 50,000 |
| Fire loops, pumps, hydrants | 75,000 | 90,000 | 110,000 | 130,000 |
| Fire pond or tank | 40,000 | 45,000 | 55,000 | 70,000 |
| Roads and fencing | 35,000 | 40,000 | 50,000 | 70,000 |
| Miscellaneous outside slabs | 20,000 | 30,000 | 45,000 | 70,000 |
| Water well | 20,000 | 20,000 | 25,000 | 30,000 |
| Total site preparation | 330,000 | 400,000 | 515,000 | 660,000 |
| TOTAL BUILDING AND SITE | 1,760,000 | 2,202,000 | 2,652,000 | 3,572,000 |

[1]*Prefabricated steel insulated buildings with slabs, footings, lighting, heating, sprinklers, and finishing.*
[2]*Land at $2000 per acre.*

Table B-4.—Estimated equipment and installation costs (M dollars) for particleboard plants of different capacities in the Black Hills (1978)

| Equipment category | Plant capacity (MM $ft^2$ per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | Wood raw material | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| | Press size | | | | | |
| | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Raw material receiving and storage | 374 | 374 | 374 | 374 | 574 | 713 |
| Milling and drying | 1,069 | 1,069 | 1,207 | 1,207 | 1,809 | 2,629 |
| Blending | 451 | 451 | 451 | 451 | 583 | 701 |
| Forming and pressing | 3,005 | 3,395 | 3,005 | 3,395 | 4,195 | 5,305 |
| Sanding and sawing | 922 | 1,035 | 922 | 1,035 | 1,260 | 1,351 |
| Boiler and fuel preparation | 1,210 | 1,210 | 1,305 | 1,305 | 1,690 | 2,125 |
| Auxiliary equipment | 473 | 473 | 473 | 473 | 620 | 739 |
| Subtotal processing equipment | 7,504 | 8,007 | 7,737 | 8,240 | 10,731 | 13,563 |
| Mobile equipment | 70 | 70 | 70 | 70 | 110 | 140 |
| Freight allowance | 150 | 170 | 160 | 180 | 200 | 240 |
| TOTAL EQUIPMENT AND INSTALLATION | 7,724 | 8,247 | 7,967 | 8,490 | 11,041 | 13,943 |

Table B-5.—Estimated salaries (dollars) of key personnel during the pre-startup period for the 67.0- and 100.0-MM $ft^2$-per-year particleboard plants in the Black Hills (1978)[1]

| Key personnel | Pre-startup salary |
|---|---|
| General manager | 66,000 |
| Plant engineer | 25,000 |
| Plant superintendent | 17,000 |
| Technical director | 14,000 |
| Sales manager | 14,000 |
| Maintenance foreman | 12,000 |
| First shift foreman | 9,000 |
| Chief electrician | 9,000 |
| Chief millwright | 9,000 |
| Shift #1 key operators | 32,000 |
| Shift #2 key operators | 16,000 |
| Total | 223,000 |

[1] *A total pre-startup cost of $198,000 for the 33.5-MM $ft^2$-per-year plants excludes the salary of a plant engineer.*

Table B-6.—Estimated requirements for wood, chemicals, and electric power for particleboard plants of different capacities in the Black Hills

| | Plant capacity (MM ft² per year) | | | | | |
|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | 100.0 |
| | Wood raw material | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| | Press size | | | | | |
| **Requirement category** | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 9-foot 16-opening | 5- × 18-foot 8-opening | 5- × 18-foot 16-opening | 5- × 18-foot 24-opening |
| Daily production 325 days/year | | | | | | |
| Thousand square feet (3/4-inch basis) | 103.1 | 103.1 | 103.1 | 103.1 | 206.2 | 307.7 |
| Thousand cubic meters[1] ($m^3$) | 182.5 | 182.5 | 182.5 | 182.5 | 365.0 | 544.6 |
| Tons[2] | 141.8 | 141.8 | 141.8 | 141.8 | 283.5 | 423.1 |
| Hourly production (22 hours/day) | | | | | | |
| Square feet | 4,686 | 4,686 | 4,686 | 4,686 | 9,373 | 13,986 |
| Pounds | 12,887 | 12,887 | 12,887 | 12,887 | 25,776 | 38,462 |
| Wood requirements[3] | | | | | | |
| Dry shavings | | | | | | |
| Annual ovendry tons | 39,948 | 39,948 | 26,633 | 26,633 | 49,004 | 49,290 |
| Daily ovendry tons | 122.92 | 122.92 | 81.95 | 81.95 | 150.78 | 151.66 |
| Green sawdust | | | | | | |
| Annual ovendry tons | 13,316 | 13,316 | 26,633 | 26,633 | 57,526 | 68,370 |
| Daily ovendry tons | 40.97 | 40.97 | 81.95 | 81.95 | 177.00 | 210.37 |
| Green chips | | | | | | |
| Annual ovendry tons | — | — | — | — | — | 41,340 |
| Daily ovendry tons | — | — | — | — | — | 127.2 |
| Chemical requirements[4] | | | | | | |
| Resin | | | | | | |
| Annual (tons) | 4,003 | 4,003 | 4,003 | 4,003 | 8,007 | 11,950 |
| Daily (pounds) | 24,641 | 24,641 | 24,641 | 24,641 | 49,274 | 73,540 |
| Wax | | | | | | |
| Annual (tons) | 536 | 536 | 536 | 536 | 1,072 | 1,600 |
| Daily (pounds) | 3,299 | 3,299 | 3,299 | 3,299 | 6,598 | 9,846 |
| Electrical power | | | | | | |
| Connected horsepower | 5,080 | 5,080 | 5,800 | 5,800 | 7,935 | 8,935 |
| KW demand | 2,450 | 2,450 | 2,780 | 2,780 | 3,800 | 4,280 |
| Annual use megawatt hours | 14,658 | 14,658 | 16,803 | 16,803 | 23,238 | 26,241 |
| Daily use kilowatt hours | 45,100 | 45,100 | 51,700 | 51,700 | 71,500 | 80,740 |

[1] *1,000 square feet of 3/4-inch board = 1.77 $m^3$.*
[2] *1,000 square feet of 3/4-inch board = 1.375 tons.*
[3] *1,000 square feet of 3/4-inch board requires 3,180 o.d. pounds of wood raw material.*
[4] *1,000 square feet of 3/4-inch board requires 239 pounds of resin and 32 pounds of wax (7.0% resin and 0.9% wax content).*

Table B-7.—Estimated availability and average cost of wood raw materials at Whitewood, S. Dak., and Newcastle, Wyo., from different sawmill locations in the Black Hills (1978)

| | Plant capacity (MM ft² per year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 33.5 | | | | 67.0 | | 100.0 | |
| | Wood raw material | | | | | | | |
| | 75% Dry shavings 25% Green sawdust | | 50% Dry shavings 50% Green sawdust | | 46% Dry shavings 54% Green sawdust | | 31% Dry shavings 43% Green sawdust 26% Green chips | |
| | Particleboard plant location | | | | | | | |
| Sawmill location | Whitewood | Newcastle | Whitewood | Newcastle | Whitewood | Newcastle | Whitewood | Newcastle |
| | M o.d. tons | | | | | | | |
| Spearfish, S. Dak. | 9.8 | 9.8 | 17.1 | 17.3 | 17.5 | 17.5 | 31.4 | 16.9 |
| Hulett, Wyo. | 5.6 | 5.6 | — | — | 11.8 | 11.8 | 23.1 | 23.1 |
| Sturgis, S. Dak. | 3.3 | 3.3 | 6.2 | — | 7.1 | 7.1 | 13.7 | 8.2 |
| Piedmont, S. Dak. | 8.4 | 8.4 | 16.2 | — | 17.7 | 17.7 | 20.8 | 20.8 |
| Hill City, S. Dak. | 8.0 | 8.0 | — | 14.0 | 14.1 | 14.1 | 13.4 | 26.4 |
| Custer, S. Dak. | 5.6 | 5.6 | — | 11.0 | 11.8 | 11.8 | 13.8 | 23.1 |
| Newcastle, Wyo. | 5.6 | 5.6 | — | 11.0 | 10.3 | 11.8 | 13.8 | 23.1 |
| Whitewood, S. Dak. | 7.0 | 7.0 | 13.8 | — | 16.2 | 14.7 | 29.0 | 17.4 |
| Total | 53.3 | 53.3 | 53.3 | 53.3 | 106.5 | 106.5 | 159.0 | 159.0 |
| | dollars | | | | | | | |
| Average cost | 8.48 | 11.47 | 5.67 | 9.31 | 8.49 | 11.46 | 11.00 | 13.37 |

Table B-8.—Estimated fuel requirements and sources for particleboard plants of different capacities in the Black Hills (1978)

| Fuel requirement and source | Plant capacity (MM ft² per year) | | | |
|---|---|---|---|---|
| | 33.5 | | 67.0 | 100.0 |
| | Wood raw material | | | |
| | 75% Dry shavings 25% Green sawdust | 50% Dry shavings 50% Green sawdust | 46% Dry shavings 54% Green sawdust | 31% Dry shavings 43% Green sawdust 26% Green chips |
| Requirements | | | | |
| Process steam-(MM pounds[1]) | | | | |
| Annual | 118 | 111 | 186 | 240 |
| Daily | 0.363 | 0.341 | 0.572 | 0.738 |
| Wet dryers (MM Btu) | | | | |
| Annual | 50,700 | 101,075 | 218,725 | 416,650 |
| Daily | 156 | 311 | 673 | 1,282 |
| Source | | | | |
| Dry fuel from trim and dust generation-(o.d. tons[2]) | | | | |
| Annual | 11,190 | 11,190 | 22,376 | 33,401 |
| Daily | 34.4 | 34.4 | 68.8 | 102.8 |
| Bark-o.d. (tons equivalent[3]) | | | | |
| Annual | 1,013 | 4,552 | 6,891 | 14,219 |
| Daily | 3.1 | 14.0 | 21.2 | 43.8 |
| Hot stack gases (MM Btu) | | | | |
| Annual | 16,800 | 15,372 | 25,955 | 31,532 |
| Daily | 52 | 47 | 80 | 97 |
| Natural gas (MM ft³)[4] | | | | |
| Annual | 9 | 42 | 68 | 139 |
| Daily | .028 | .129 | .209 | .428 |

[1]*One pound of steam = 1,333 Btu's.*
[2]*One ton of dry fuel from trim and dust = 16 million Btu's.*
[3]*One dry ton equivalent of wet bark = 12 million Btu's, assuming 75% of heat is recoverable as compared to dry fuel.*
[4]*Natural gas will only be used as a standby fuel. One cubic foot of natural gas = 1,000 Btu's.*

Table B-9.—Estimated employment (number of full-time equivalent jobs) for particleboard plants of different capacities (gross MM ft² per year) in the Black Hills

| Type of job | Plant capacity 33.5 | 67.0 | 100.0 |
|---|---|---|---|
| Manufacturing[1] | | | |
| Skilled | 42 | 63 | 75 |
| Unskilled | 8 | 12 | 14 |
| Maintenance and repair[2] | 9 | 11 | 15 |
| Administration and sales[3] | 14 | 18 | 22 |
| Total | 73 | 104 | 126 |

[1]*Included in processing labor costs in the discounted cash flow analysis (DCFA) program.*
[2]*Included in factory overhead costs in the DCFA program.*
[3]*Included in administrative overhead costs in the DCFA program.*

Table B-10.—Estimated factory and administrative overhead costs (dollars) for particleboard plants of different capacities (gross MM ft² per year) in the Black Hills

| Overhead costs | Plant capacity 33.5 | 67.0 | 100.0 |
|---|---|---|---|
| Factory overhead | | | |
| Operating and maintenance supplies | $284,750 | $536,000 | $ 800,000 |
| Maintenance labor | 144,000 | 176,000 | 240,000 |
| Total | 428,750 | 712,000 | 1,040,000 |
| Administrative overhead | | | |
| Salaries and payroll[1] | 224,000 | 288,000 | 352,000 |
| Office maintenance and travel expense | 80,000 | 120,000 | 140,000 |
| Insurance and taxes | 150,000 | 234,500 | 300,000 |
| Total | 454,750 | 642,500 | 792,000 |

[1]*Including sales personnel salaries.*

Table B-11.—Depreciation (dollars) for a 100.0 MM ft² per year facility

| Capital assets | Year [1]0 | 1 | 2 | 3 | 4 | 5 | 6-10 |
|---|---|---|---|---|---|---|---|
| Land | 80,000 | | | (Nondepreciable) | | | |
| Site preparation[2] | 580,000 | 29,000 | 29,000 | 29,000 | 29,000 | 29,000 | 29,000 |
| Buildings[3] | 2,912,000 | 64,711 | 64,711 | 64,711 | 64,711 | 64,711 | 64,711 |
| Process machinery[4] | 13,800,000 | 2,484,000 | 1,987,200 | 1,589,760 | 1,271,810 | 1,017,450 | 813,950 |
| Mobile equipment[5] | | | | | | | |
| 1st 5 years | 143,000 | 25,740 | 25,740 | 25,740 | 25,740 | 25,740 | — |
| 2nd 5 years | — | — | — | — | — | 182,000 | 32,760 |
| Miscellaneous[6] | 4,288,000 | 378,720 | 378,720 | 378,720 | 378,720 | 378,720 | 378,720 |
| Total | 21,803,000 | 2,982,171 | 2,485,371 | 2,087,931 | 1,769,981 | 1,515,621 | 1,319,141 |

[1]*Values at time zero are costs of capital assets.*
[2]*Straight line depreciation over 20 years with no salvage value.*
[3]*Straight line depreciation over 45 years with no salvage value.*
[4]*Double declining depreciation over first 5 years, straight line over 6-10 years with salvage value 10% of initial cost.*
[5]*Straight line depreciation over 5 years with salvage value of 10% of original cost.*
[6]*Straight line depreciation over 10 years with salvage value of 12% of original cost.*

Table B-12.—Financial summary from the discounted cash flow analysis program with yearly unit sales (M ft², 3/4-inch basis), break-even prices, costs, depreciation, profits, earnings, and cash flow (dollars) for the 100 MM ft² particleboard facility in the Black Hills (1978)[1]

| Year-end financial values | Year 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit sales | 46,700 | 98,800 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 | 100,000 |
| Unit price per M ft² | 173.46 | 182.13 | 191.24 | 200.80 | 210.84 | 221.39 | 232.45 | 244.08 | 256.28 | 269.10 |
| Gross sales | 8,100,645 | 17,994,881 | 19,124,114 | 20,080,320 | 21,084,336 | 22,138,553 | 23,245,480 | 24,407,754 | 25,628,142 | 26,909,549 |
| Interest income or expense | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gross revenue | 8,100,645 | 17,994,881 | 19,124,114 | 20,080,320 | 21,084,336 | 22,138,553 | 23,245,480 | 24,407,754 | 25,628,142 | 26,909,549 |
| Raw material cost | 2,987,866 | 6,637,285 | 7,053,795 | 7,406,485 | 7,776,809 | 8,165,649 | 8,573,932 | 9,002,629 | 9,452,760 | 9,925,398 |
| Processing labor | 1,097,904 | 1,495,200 | 1,569,960 | 1,648,458 | 1,730,881 | 1,817,425 | 1,908,296 | 2,003,711 | 2,103,897 | 2,209,091 |
| Selling expense | 810,065 | 1,799,488 | 1,912,411 | 2,008,032 | 2,108,434 | 2,213,855 | 2,324,548 | 2,440,775 | 2,562,814 | 2,690,955 |
| Total variable cost | 4,895,835 | 9,931,973 | 10,536,166 | 11,062,975 | 11,616,123 | 12,196,930 | 12,806,776 | 13,447,115 | 14,119,471 | 14,825,444 |
| Variable cost per M ft² | 104.84 | 100.53 | 105.36 | 110.63 | 116.16 | 121.97 | 128.07 | 134.47 | 141.19 | 148.25 |
| Profit contribution | 3,204,811 | 8,062,907 | 8,587,948 | 9,017,345 | 9,468,212 | 9,941,623 | 10,438,704 | 10,960,639 | 11,508,671 | 12,084,105 |
| Administrative overhead | 792,000 | 831,600 | 873,108 | 916,839 | 962,681 | 1,010,815 | 1,061,356 | 1,114,424 | 1,170,145 | 1,228,652 |
| Factory overhead | 1,046,544 | 1,098,871 | 1,153,815 | 1,211,505 | 1,272,081 | 1,335,685 | 1,402,469 | 1,472,593 | 1,546,222 | 1,623,533 |
| Total fixed cost | 1,838,544 | 1,930,471 | 2,026,995 | 2,128,344 | 2,234,762 | 2,346,500 | 2,463,825 | 2,587,016 | 2,716,367 | 2,852,185 |
| Facilities cost | 0 | 0 | 0 | 0 | 182,000 | 0 | 0 | 0 | 0 | – 4,548,220 |
| Working capital | 689,912 | 97,985 | 88,774 | 93,213 | 97,873 | 102,767 | 107,905 | 113,301 | 118,966 | – 2,498,279 |
| Investment | 689,912 | 97,985 | 88,774 | 93,213 | 279,873 | 102,767 | 107,905 | 113,301 | 118,966 | – 7,046,499 |
| Depreciation | 2,982,171 | 2,485,371 | 2,087,931 | 1,769,981 | 1,515,621 | 1,319,141 | 1,319,141 | 1,319,141 | 1,319,141 | 1,319,141 |
| After tax profit | – 840,270 | 3,290,774 | 2,325,971 | 2,661,890 | 2,973,271 | 3,263,511 | 3,460,984 | 3,668,331 | 3,886,045 | 4,114,645 |
| After tax earnings | 2,141,901 | 5,776,145 | 4,413,902 | 4,431,871 | 4,488,892 | 4,582,652 | 4,780,125 | 4,987,472 | 5,205,186 | 5,433,786 |
| After tax net cash flow | 1,451,989 | 5,678,160 | 4,325,128 | 4,338,658 | 4,209,019 | 4,479,885 | 4,672,220 | 4,874,171 | 5,086,220 | 12,480,285 |
| Accumulated net cash flow | – 21,338.6M | – 15,660.4M | – 11,335.3M | – 6,996.6M | – 2,787.6M | 1,692,3M | 6,364.5M | 11,238.6M | 16,324.9M | 28,805.2M |

[1] *The program calculated variable costs to be 0.5531, fixed costs 0.1944, taxes 0.1145, and after tax profits 0.1380 of total sales during the 10-year period. The internal rate of return was 15%.*

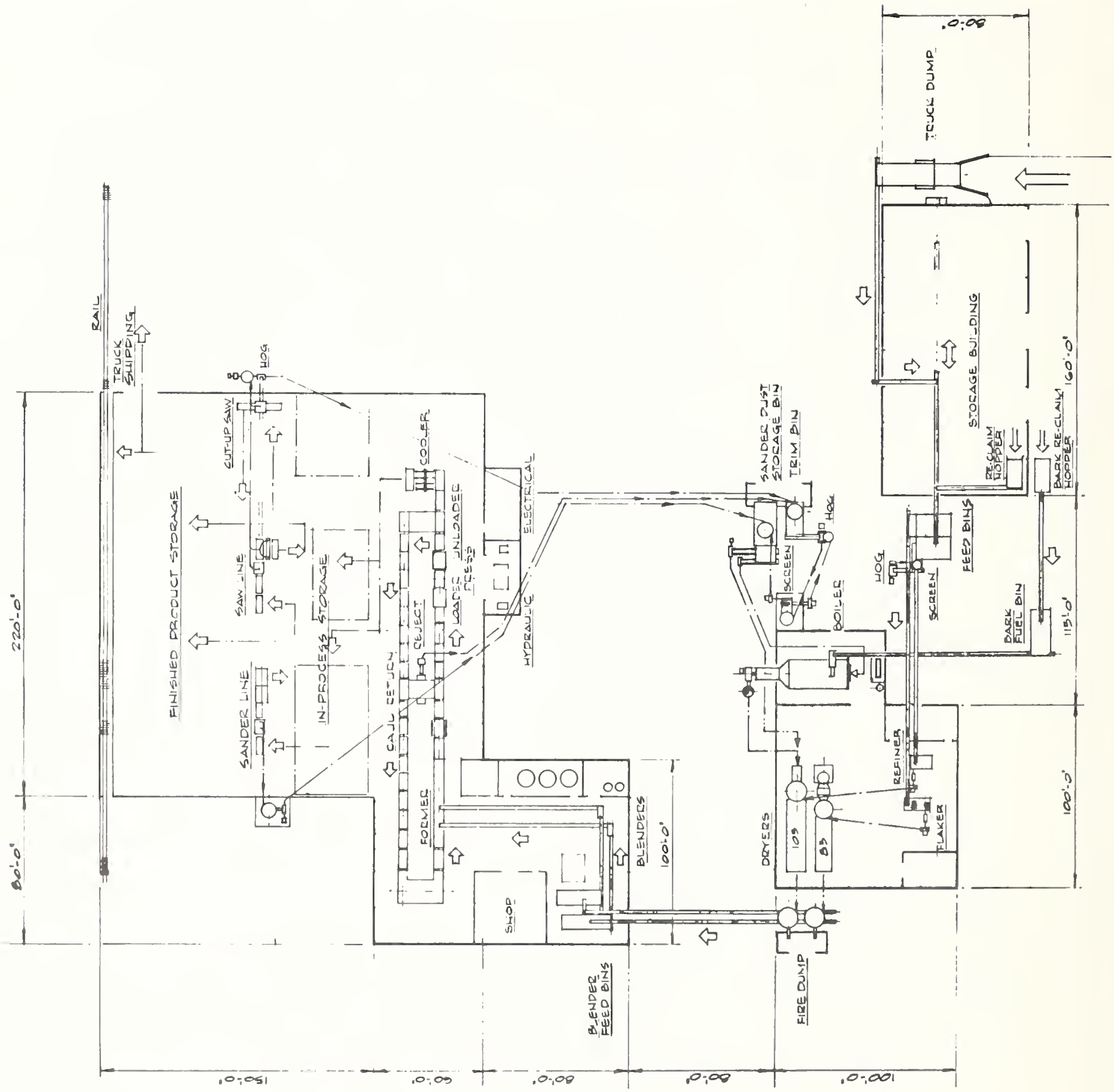



**Figure B-1.—Plant and equipment layout for a 33.5-MM ft², 3/4-in-basis particleboard facility in the Black Hills.**

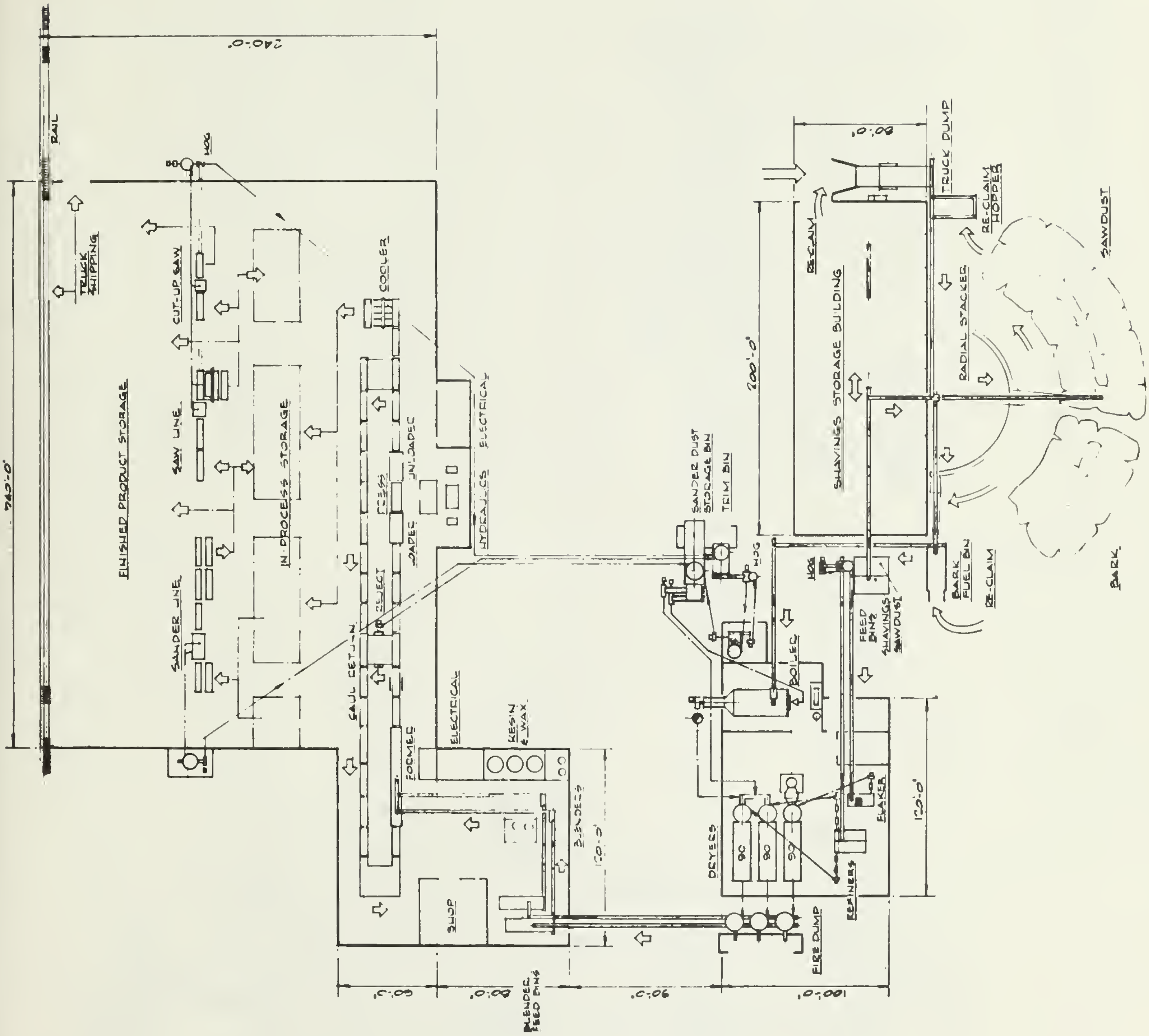



Figure B-2.—Plant and equipment layout for a 67.0-MM ft², 3/4-in-basis particleboard facility in the Black Hills.

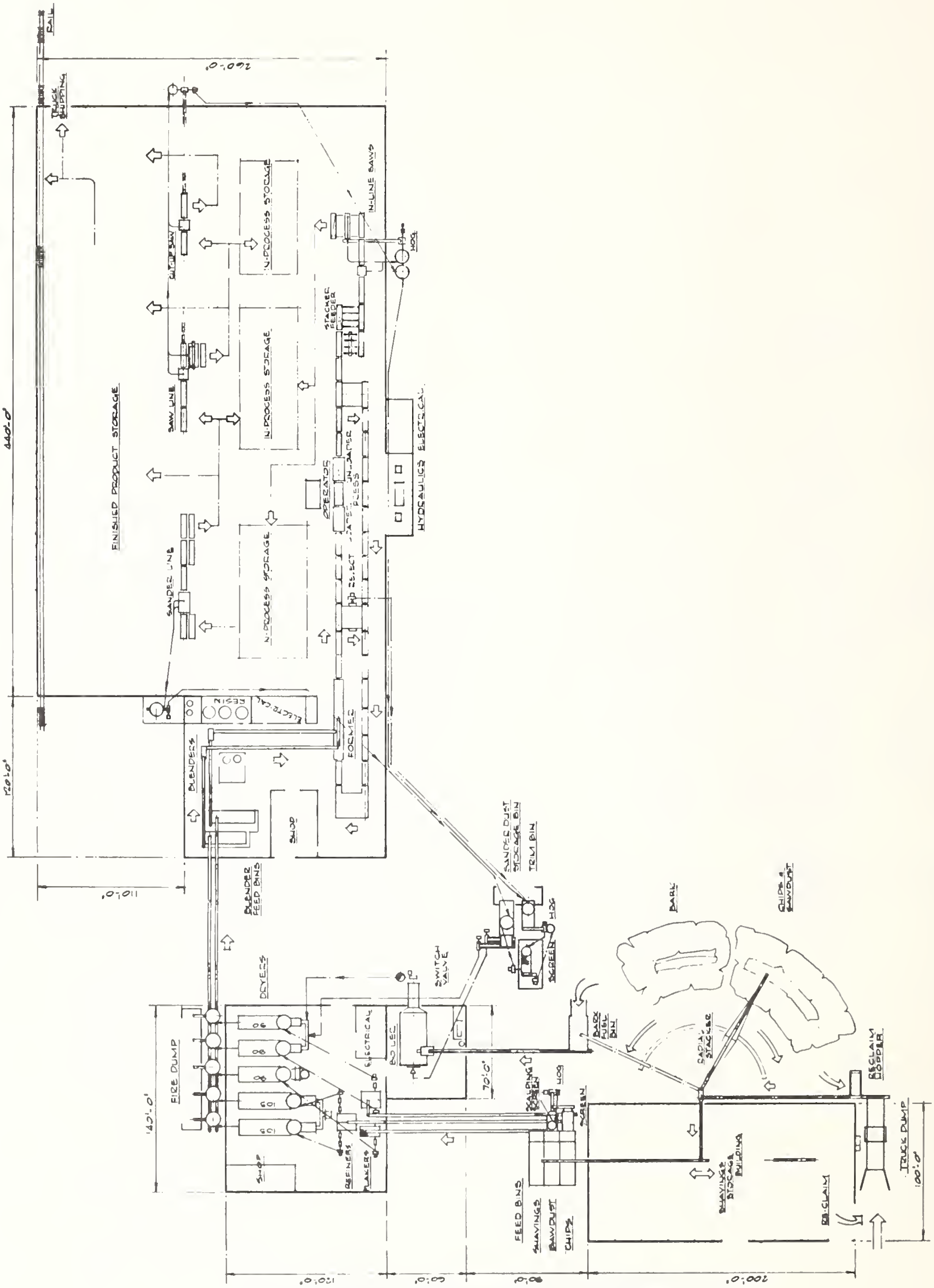



Figure B-3.—Plant and equipment layout for a 100.0-MM ft², 3/4-in-basis particleboard facility in the Black Hills.

Markstrom, Donald C. and Harold E. Worth. 1981. Economic potentials for particleboard production in the Black Hills. USDA Forest Service Resource Bulletin RM-5, 30 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area.

**Keywords:** Particleboard, forest products, *Pinus ponderosa*

Markstrom, Donald C. and Harold E. Worth. 1981. Economic potentials for particleboard production in the Black Hills. USDA Forest Service Resource Bulletin RM-5, 30 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area.

**Keywords:** Particleboard, forest products, *Pinus ponderosa*

Markstrom, Donald C. and Harold E. Worth. 1981. Economic potentials for particleboard production in the Black Hills. USDA Forest Service Resource Bulletin RM-5, 30 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area.

**Keywords:** Particleboard, forest products, *Pinus ponderosa*

Markstrom, Donald C. and Harold E. Worth. 1981. Economic potentials for particleboard production in the Black Hills. USDA Forest Service Resource Bulletin RM-5, 30 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A Black Hills plant producing 100 million square feet of ponderosa pine particleboard (3/4-inch basis) should produce attractive financial returns and be economically viable in soft markets. The north central region of the United States, together with Wyoming and Colorado, seems to be the prime marketing area.

**Keywords:** Particleboard, forest products, *Pinus ponderosa*

U.S. Department of Agriculture
Forest Service

# Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

## RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

## RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Bottineau, North Dakota
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526